

AN ECOLOGICAL LAND SURVEY OF THE LOCKHART RIVER MAP AREA, NORTHWEST TERRITORIES

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AN ECOLOGICAL LAND SURVEY OF THE LOCKHART RIVER MAP AREA, NORTHWEST TERRITORIES

prepared for

Lands Directorate, Environment Canada,
Ottawa, Ontario

by

S.W. Bradley, J.S. Rowe, and C. Tarnocai

with the assistance of
G.R. Ironside

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THE AUTHORS:

S.W. Bradley, formerly of the Department of Plant Ecology, University of Saskatchewan, Saskatoon, Saskatchewan.

J.S. Rowe, Department of Plant Ecology, University of Saskatchewan, Saskatoon, Saskatchewan.

C. Tarnocai, Land Resource Research Institute, Agriculture Canada, Ottawa, Ontario.

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Lands Directorate
Environment Canada
Ottawa
Canada
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PREPARATION OF THE FINAL REPORT:

Coordination -- G.R. Ironside, Lands Directorate, Environment Canada, Ottawa.

Word processing -- N. Archambault, Systemhouse Limited, Ottawa; H. Villeneuve, Lands Directorate, Environment Canada; and the Talking Typewriter, Ottawa.

Editing -- L. Lee, Ottawa, Ontario; R. Tabacnik, Words Associated, Wakefield, Quebec.

Format and paste-up -- Words Associated, Wakefield, Quebec.

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SECTION A

INTRODUCTION

INTRODUCTION

This text and the accompanying maps constitute a report on part of a larger project that was designed in 1975 to study fire-terrain relationships in the Northwest Territories. It was recognized then that a background ecological map can be valuable in various ways -- not only to orient field workers studying particular processes (e.g., succession and nutrient regime), but also as an integrative end in itself. Ecological maps express concepts about the meaning of landscapes and ideas about how their components interact. They represent hypotheses that can be tested and that serve a heuristic function. Moreover, they have practical values for land management.

The biological-physical landscape systems of the Canadian north are not well known, particularly in the Subarctic. Many isolated investigations have been carried out over the years, but there still is no adequate geological or geomorphological coverage, no comprehensive flora or soil survey, and, least of all, any relating of these landscape components to one another. However, as northern development proceeds, as mines and transportation corridors are opened, and as renewable resource use and recreational activities expand, the need increases for studies that bring together and integrate the scattered information in a form that is relevant to land use planning.

The project reported here was originally planned as a two-year study. However, because of a change of personnel, the work had to be accomplished in one season. The area studied is large, comprising approximately 200,000 km², of which about one-quarter is surface water. It extends from 60° to 66° latitude and from 106° to

112° longitude and coincides with the Lockhart River map sheet (NTS 75 in the old map series and NP-12/13 in the new; map scale 1:1,000,000). We call this the Lockhart River Map Area (Figure 1), abbreviated to LRMA.

Because of the size of the area and the time limitations of the survey, a 'broad brush' approach was taken with the intention of providing a framework inventory for resource management at the general rather than the site-specific level. Therefore, the chief emphasis was on the preparation of two maps: one primarily a soils map based on a LANDSAT mosaic and the other a synthesizing ecological map (pages 96 and 20 respectively).

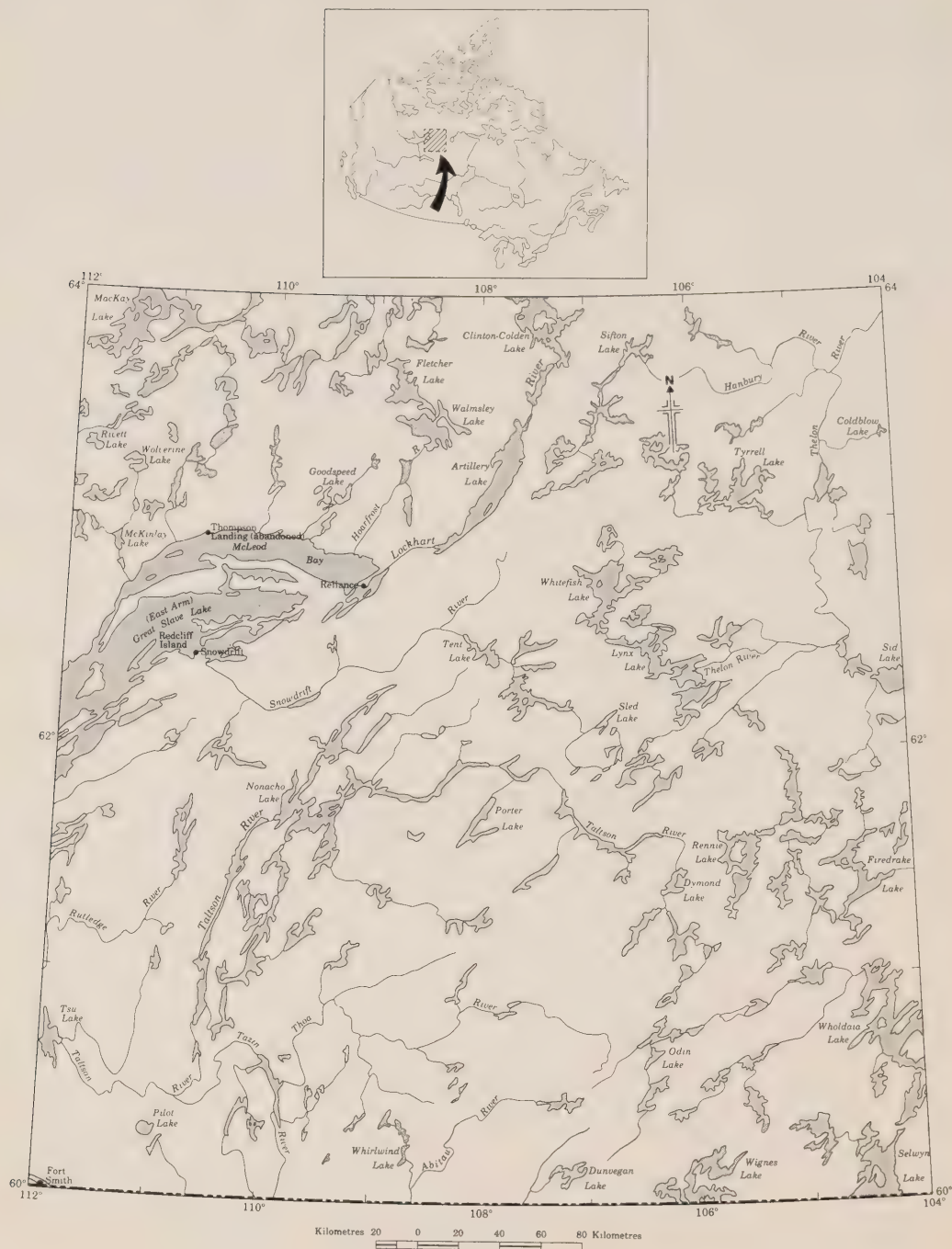
This project is also a contribution to the concepts and the methodology of ecological land classification; as such, it is motivated by an interest in the problems of integrating the biological and physical components of landscapes.

The botanical names used in this report can be found with their authorities in the following works:

"Checklist of the Vascular Plants of Continental Northwest Territories, Canada". A.E. Porsild and W.J. Cody. 1968. Plant Research Institute, Canada Department of Agriculture, Ottawa.

"How to know the Lichens". M.E. Hale. 1979 (2nd ed.). Wm. C. Brown Co., Dubuque, Iowa.

"Mosses of the Great Lakes Forest". H. Crum. Contributions from the University of Michigan Herbarium, Vol. 10, p. 1-404. University Herbarium, University of Michigan, Ann Arbor, Michigan.



SECTION B

METHODS

METHODS

1. PREPARATORY WORK

S.W. Bradley joined the program early in 1977, accomplishing most of the studies in a little over a year. Preparation for field work involved examination of available air photo mosaics (at the 1:60,000 scale, covering the LRMA from 63° latitude south to 60° latitude), from which preliminary maps of surficial geology were drawn. LANDSAT imagery, both colour-infrared frames and black-and-white mosaics, were also examined in the search for obvious subdivisions into ecoregions and subregions. Concurrently, detailed studies of the literature provided the thematic understanding necessary to interpret features visible on the medium- and small-scale imagery. C. Tarnocai, who also joined the project in 1977, drew up a preliminary soils map at 1:1,000,000 from the LANDSAT mosaic, providing another useful physiographic interpretation of the area.

Visits were made to the Air Photo Library in Ottawa to select flight lines of photos that gave a systematic representation of the terrain at 1:30,000. These images were studied under the stereoscope to pick out recognition features of landform, vegetation, and permafrost that showed regional and local (topographic) change in the LRMA. Tentative sketch maps were made of boundaries and transition zones. By these procedures, a good appreciation of the terrain from Boreal Forest to Shrub Tundra was gained prior to the field season.

2. FIELD WORK

Initially, four long reconnaissance flights were taken over the LRMA to check hypotheses developed in the preliminary studies and to provide information as to the desirability and feasibility of detailed studies on the ground. During clear-weather flights, notes on features identified as ecologically important (e.g., treed or treeless peat plateaus, vegetated or non-vegetated lake-shores) were marked on 1:250,000 maps.

The classification framework gelled around five major units (ecoregions and subregions) on the basis of physiography and vegetation patterns ('formations'); they are named Mid Boreal, High Boreal, Low Subarctic, High Subarctic Forest Tundra, and High Subarctic Shrub Tundra. Only a few sampling sites were located in the first unit, most being

distributed within the last four in proportion to their areal extent.

Specific locations for studies on the ground were chosen to sample major patterns of surficial materials and their vegetations (ecosections). Particular attention was given to High Boreal drift/bedrock and Low and High Subarctic till. A more refined selection of sites for 'ground truth' was made by reference to catenary sequences of vegetation on landform topographic and drainage gradients.

Intensive sampling of vegetation at each visually homogeneous site was by ten one-half square meter quadrats systematically spaced along a 50 m line. The frequency and relative abundance of all species were tallied. Presence lists from outside the quadrats were also made. The diameter of all trees within 5 m of the central line was recorded as well as representative ages and heights. A soil pit was dug and the profile described and photographed; samples were collected for standard laboratory analyses (at the University of Manitoba) of physical and chemical properties.

Additional descriptions (without quantitative sampling) were made at many sites. This usually involved a rapid visual estimate of the cover of each broad structural component (trees, shrubs, forbs, graminoids, mosses, lichens, and bare ground), a listing of dominants (covering more than 15% of the surface), a soil pit description, and notes on such features as fire history, stand age, and animal activity.

3. SUBSEQUENT SYNTHESIS

The final phase was the synthesis of field data and thematic studies, in the winter of 1977 and the spring of 1978, to yield relationships between landforms, vegetation, and soils. Results are presented in the maps and text that follow, providing a foundation for ecological land classification in this part of the western Subarctic.

The report has two main parts: first the integrated physical and biological information whose expression is the ecological map, and then the thematic information. The section on 'Paleobotany' under 'Vegetation History' is the contribution of J.C. Ritchie, Scarborough College, University of Toronto. The section on 'Soils and Permafrost' was written by C. Tarnocai.

SECTION C
RATIONALE

RATIONALE

The land surface bears a variety of resources such as plants, animals, soils, and water that traditionally have been inventoried and managed individually. However, the land surface also comprises a wide range of environments which, according to interests and purposes foreseen, can be delineated and classified in various ways. In ecological land classification, an attempt is made to view landscapes not just as aggregations of separate biologic and earth resources, but as ecological systems with functionally related parts. In this approach, map boundaries are located by reference to system boundaries (i.e., to the transition zones between areas of co-varying climate, biota, soils, landforms, and waterforms). The resulting units provide a spatial stratification that is particularly significant for integrated resource management.

The focus on dynamic interactions in the landscape leads directly to climate as the motive force. The different environments recognized at the earth's surface at various scales represent different exchange regimes of solar energy and of materials (such as water) that are moved by solar energy. This is as true at the level of the local hillslope as at the level of the continental zone. Ecological land classification can therefore be conceived as a method of dividing the surface into different energy regimes, large and small, in a hierarchy.

Climate control is exerted through air mass movements over continental areas and, within such large air mass zones, through surface features that affect albedo, advection, heat storage, etc. Thus, relief, geological substratum, surface water, topography, and vegetation acting in concert modify and shape the more or less unique climatic regimes of geographical place. It is to the elements of 'control' that we look in mapping terrain, and the specific element selected as a boundary discriminator at any place is that which, relative to the others, is perceived to be most influential at the chosen scale. For example, substantial changes in relief (as at escarpments) and in geological materials (as at surface contacts) are perceived to mark macroclimatic boundaries, while the lesser changes in topographic slope and aspect mark microclimatic boundaries.

Many of the difficulties of rationalizing the methods of land classification are overcome by assuming that the chief aim is to differentiate earth surface environments according to climatic regime. The landscape components

that control and modify energy exchange at all scales -- primarily large and small landforms -- provide the stable, semi-permanent features by which similar climatic regimes are recognized. The biologic components -- plants and animals and soils -- indicate, by their patterning to landforms, the positioning and significance of climatic boundaries.

All land units, regardless of size, are land ecosystems powered by climatic energy. Only the controls that modify climatic regime at the various scales differ. Those regions that are considered to be 'zonal' (in the soil scientist's sense) and that express climatic influences directly over broad areas are necessarily uniform in geologic-topographic surficial features; climate is apparently 'uncontrolled' and it alone is identified as dominant in the system. On the other hand, 'intrazonal' areas are non-uniform in surface features; climatic control is expressed in them by relief-topography and/or geological material. The zonal idea is not invalidated by heterogeneity at the earth's surface. Under such conditions, what would otherwise be a homogeneous (zonal) climatic regime is broken by each change in relief and geology into smaller, more localized climatic regimes. The tendency has been to assume that these smaller parts are orographic regions or geologic regions, rather than simply climatic regions at a larger scale.

The boundaries of environmentally significant land units keyed to climatic regime will necessarily be differentiated by criteria that change from place to place. Thus, a large unit of land may be bounded on one side by reference to a change in air mass climate, on another side by a change in relief, and on a third side by a change in geological material. Similarly, a smaller unit of land may be bounded on different sides by changes in aspect, exposure, slope angle, or water-table depth. The varying boundary criteria do not invalidate the uniformity of the climatic regime within. Indeed, the inconsistent boundary criteria are necessary to establish a consistent climatic core.

Is the approach objective? Everyone brings to land classification a set of personal assumptions and preferences expressed in his or her aims and methods. To be objective is to expose explicitly the underpinnings of the system. Readers can then understand the approach (it is reproducible); they can judge its degree of arbitrariness and internal logic, and they can reject it or accept and build on it. Thus, a basis is provided for advancing the field.

SECTION D

**CRITERIA FOR THE
ZONATION**

CRITERIA FOR THE ZONATION

1. INTRODUCTION

It is assumed that climate is the 'driving variable' of terrain, through surface exchanges of energy and moisture. Ecological theory makes it clear that climate does not stand apart from other components of the landscape but is always expressed through interactions with them. Nevertheless, the conceptual separation of climate from the other components provides a clear focus for ecological land classification and a logic by which the great variety of terrain features can be related and ordered at all scales.

Unlike landforms and vegetation, climate is not directly perceptible; it is inferred from ecological indicators that also provide a visible means of extrapolating the point measurements available from widely scattered meteorological stations. Many land classifications have the advantage of working in areas where large physiographic changes (in relief and/or geology) provide indisputable boundaries with climatic significance. However, in the LRMA, only small physiographic changes are discernible over great distances. Broad regions can still be defined by attention to the spatial patterning of vegetation and soils, peatlands, and permafrost. In this section, some of the clues used to guide the regionalization are briefly discussed.

2. ECOLOGICAL INDICATORS

The surface mantle throughout much of the LRMA is a coarse siliceous drift derived from Precambrian granitic and detrital sedimentary rock. Between the proglacial and postglacial inundation basins of the west (Great Slave Lake-Slave River) and of the east (Thelon Lake-Wholdaia Lake), the upland tills are a loamy sand texture, frequently very bouldery.

Peats are also relatively homogeneous, consisting usually of poorly decomposed fibric Sphagnum in bogs and mesic to humic sedge-moss remains in fens.

If surficial materials are relatively uniform over a large area, as is the case with the glacial drift and the peats of the LRMA, then climatic differences should show up both in regional changes of the physiognomy of vegetation and in those aspects of landform that respond to changing moisture and thermal regimes. Soils will tie in to the patterns through their relationships with landform and vegetation.

Reconnaissance of the area revealed a number of climatic-ecological clues in the terrain. They are not equally useful or recognizable on aerial photographs, but a list of all of them is presented in Table 1 in order of appearance from southwest to northeast (i.e., proceeding from a less rigorous to a more rigorous environment). The structural 'Peatland' features, like the 'Frost' features, apparently reflect the influence of declining mean annual temperature from the west (Mid Boreal Ecoregion) to the northeast (High Subarctic Ecoregion). A similar interpretation applies to changes in the 'Vegetation' column.

The floristic composition of communities is another indication of climatic severity. Table 2 shows some of the plants confined to the High Subarctic and the Mid Boreal ecoregions. Between these extremes in the LRMA there is a broadly adapted assemblage, including such ubiquitous species as Picea mariana and Vaccinium vitis-idaea. Species diversity also varies; it is remarkably low on well-drained sites centrally (Low Subarctic), especially for herbaceous species which show a marked increase toward both the Boreal (southern) and the Arctic (northern) zones.

Table 1: Landscape features indicative of climatic regime in the LRMA

<u>ECOREGION</u>	<u>VEGETATION</u>	<u>PEATLAND</u>	<u>FROST</u>
Mid Boreal: Slave River - Gt. Slave Lake	Closed-crown mixedwood and conifer forest; treed fens and marshes; extensive floating mats of aquatic plants in lakes.	Wooded peat plateaus and palsas.	Earth hummocks on fine-textured materials.
High Boreal: Shield Uplands	Upland and lowland closed-crown conifer forests; floating mats near shores.	Wooded peat plateaus with thermokarst features and palsas.	Earth hummocks on fine-textured materials.
Low Subarctic	Lichen Woodland with Bog Forest below; narrow marginal mats of aquatic vegetation by lake-shores.	Wooded peat plateaus and palsas; some treeless polygonal peat plateaus; rilled peat plateaus on slopes.	Frost-heaved stone fields; some polygons on peatlands.
High Subarctic: Forest Tundra	Upland Heath-Lichen tundra with Shrub Woodland below; very little aquatic vegetation; shorelines mostly bare.	Polygonal peat plateaus and peat hummocks; some eroded high-center lowland polygons; rilled peat plateaus on slopes; striped fen and frozen bog complexes.	Frost-heaved stone fields common; beaded streams; sorted nets in shallow lakes; mud boils; polygons on peatlands.
High Subarctic: Shrub Tundra	Upland 'black-lichen' tundra with Shrub-Sedge and Sedge Meadow below; no aquatic vegetation.	High-center lowland polygons and peat hummocks, tussocks, strings and circles.	Frost-heaved stone fields; nonsorted mud boils and polygons; solifluction lobes and terraces; strongly developed sorted nets in shallow lakes; upland polygons; polygons on peatlands.

Table 2: Examples of indicator plant species having regional significance

<u>High Subarctic</u>	<u>Low Subarctic</u>	<u>High and Mid Boreal</u>
<u>Graminoids</u>		
<i>Arctophila fulva</i> <i>Hierochloë alpina</i> <i>Vahlodea atropurpurea</i>	<i>Calamagrostis purpurascens</i> <i>Poa glauca</i>	<i>Agrostis scabra</i> <i>Calamagrostis neglecta</i> <i>Deschampsia caespitosa</i>
<i>Carex bigelowii</i> <i>Carex rotundata</i>	<i>Carex limosa</i> <i>Carex magellanica</i> <i>Carex siccata</i> <i>Eriophorum russeolum</i>	<i>Carex atherodes</i> <i>Carex disperma</i> <i>Carex rostrata</i>
<i>Juncus arcticus</i> <i>Luzula confusa</i>		
<u>Herbs and Half Shrubs</u>		
<i>Armeria maritima</i> <i>Artemisia borealis</i> <i>Dryas integrifolia</i> <i>Oxyria digyna</i> <i>Parnassia kotzebuei</i> <i>Saxifraga foliolosa</i>	<i>Geocaulon lividum</i> <i>Pedicularis labradorica</i>	<i>Aralia nudicaulis</i> <i>Castilleja rupii</i> <i>Cornus canadensis</i> <i>Linnaea borealis</i> <i>Lycopodium complanatum</i>
<u>Ericoids (Heath-like Dwarf Shrubs)</u>		
<i>Arctostaphylos alpina</i> <i>Cassiope tetragona</i> <i>Diapensia lapponica</i> <i>Phyllodoce coerulea</i> <i>Rhododendron lapponicum</i>	<i>Andromeda polifolia</i> <i>Arctostaphylos rubra</i> <i>Empetrum nigrum</i> <i>Ledum decumbens</i> <i>Loiseleuria procumbens</i> <i>Vaccinium vitis-idaea</i> <i>Vaccinium uliginosum</i>	<i>Arctostaphylos uva-ursi</i> <i>Chamaedaphne calyculata</i> <i>Kalmia polifolia</i> <i>Ledum groenlandicum</i> <i>Vaccinium myrtilloides</i>
<u>Broadleaf Shrubs and Juniper</u>		
<i>Salix brachycarpa</i> ssp. <i>niphoclada</i> <i>Salix fuscescens</i> <i>Salix reticulata</i>	<i>Alnus crispa</i> <i>Salix glauca</i> <i>Salix planifolia</i> ssp. <i>planifolia</i>	<i>Alnus incana</i> <i>Juniperus communis</i> <i>Myrica gale</i> <i>Salix bebbiana</i> <i>Salix serrissima</i> <i>Viburnum edule</i>
<u>Lichens and Bryophytes</u>		
<i>Alectoria nitidula</i> <i>Alectoria ochroleuca</i> <i>Cornicularia divergens</i> <i>Thamnolia subuliformis</i>	<i>Cetraria nivalis</i> <i>Cladina mitis</i> <i>Cladonia uncialis</i> <i>Stereocaulon paschale</i>	<i>Cladina rangiferina</i> <i>Cladina stellaris</i> <i>Peltigera aphthosa</i>
<i>Dicranum elongatum</i> <i>Dicranum groenlandicum</i>	<i>Dicranum fuscescens</i> <i>Ptilidium ciliare</i>	<i>Dicranum rugosum</i> <i>Hylocomium splendens</i>

SECTION E

ECOREGIONS AND SUBREGIONS

LINE COLOR CODE

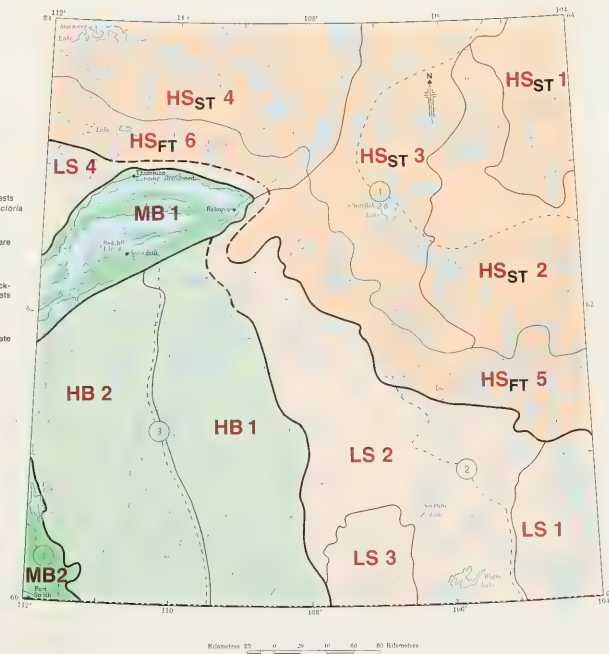
Regional Boundaries

Subregional Boundaries

District Boundaries

Other Boundaries

- 1 Cornicularia Line**—Within this line the polygonally patterned craters of drumlins are black with the wily lichens *Cornicularia* and *Alectoria*
- 2 Bog Treeline**—Eastward of the line, the polygonal peat plateaus are treeless
- 3 Pine Forest Line**—Extensive pine forests occupy the bedrock-dominated uplands west of the line; eastward black spruce forests are prominent.
- 4 Mixedwood Forest Line**—Mixed aspen and white spruce dominate west of the line; pine-spruce dominate to the east



ECOREGIONS, SUBREGIONS, AND ECODISTRICTS OF THE LOCKHART RIVER MAP AREA, NORTHWEST TERRITORIES

HS-HIGH SUBARCTIC ECOREGION

Well drained uplands dominated by tundra

ST—SHRUB TUNDRA SUBREGION

- 1. THELON ECODISTRICT**
1 (Mb / Mv)
Co 1 Heath-Lichen & Lichen-Grass
Co 2 Heath-Lichen
Ho 1 Shrub-Heath (wS)
Si 1 Sedge Meadow
- 2. TYRRELL-SID ECODISTRICT**
2 (Mb / Mv) / R
Ly 1 Heath-Lichen
Ly 1 Heath-Lichen & Lichen-Grass
R Rock Lichen
Si 1 Sedge Meadow & Shallow Bog
- 3. SIFTON-WHITEFISH ECODISTRICT**
2 (Mb / Mv) / R
Wo 1 Heath-Lichen & Shrub-Heath
Wo 2 Heath-Lichen & Shrub-Heath
Si 1 Sedge Meadow

FT—FOREST TUNDRA SUBREGION

- 4. MACKAY-WALMSLEY ECODISTRICT**
2 (Mb / Mv) / R
Wo 1 Heath-Lichen & Shrub-Heath
Wo 2 Heath-Lichen & Shrub-Heath
Si 1 Sedge Meadow & Shallow Bog
- 5. TENT-FIREDRAKE ECODISTRICT**
2 (Mb / Mv) / R
Wo 2 Shrub-Heath
Wo 1 Heath-Lichen
Si 1 Sedge Meadow & Bog (peat polygons)
- 6. RIVETT-GOODSPEED ECODISTRICT**
2 (Mb / Mv) / R
Wo 2 Shrub-Heath
Wo 1 Heath-Lichen
R Rock Lichen
Si 1 Sedge Meadow & striped Bog-and-Fen complex

LS-LOW SUBARCTIC ECOREGION

Open woodland with lichen carpet on rises, closer woodland or forest on the moister slopes. Dystric Brunisols, Gleysols and Organic Cryosols from upper to lower slopes

- 1. WHOLDAIA-SELWYN ECODISTRICT**
1 (Mb / Mv) / Ob
Po 1 Lichen-Heath Woodland (bS, wB)
Po 2 Lichen-Moss Woodland (bS, wB)
Dy 1 Bog (polygonal peat plateaus)
Dy 1 Shrub-Heath Woodland (bS, wS, wB)
- 2. PORTER-WIGNES ECODISTRICT**
2 (Mb / Mv) / Ob
Po 1 Lichen Woodland (bS, wB, IP)
Dy 1 Shrub-Heath Woodland (bS, wS, wB)
Dy 1 Bog & Bog Woodland (bS, IT)
- 3. ABITAU-DUNVEGAN ECODISTRICT**
2 (Mb / Mv) / R
Po 1 Lichen Woodland (bS, wB, IP)
Po 2 Lichen-Moss Woodland (bS)
Dy 1 Shrub-Heath Woodland (bS, wB)
Dy 1 Bog Woodland (bS, IT)
- 4. MCKINLAY ECODISTRICT**
2 (Mb / Mv) / R
Po 2 Shrub Woodland (bS)
Po 1 Lichen-Heath Woodland (bS, wB)
Dy 1 Bog Woodland (bS)

HB-HIGH BOREAL ECOREGION

Closed-crown coniferous forest on rises with moss and bog forests on lowlands. Dystric Brunisols, Gleysols and Organic Cryosols on the well drained to poorly drained positions

- 1. NONACHO-WHIRLWIND ECODISTRICT**
2 (Mb / Mv) / Ob
Na 2 Shrub-Heath Woodland (bS, IP)
Na 1 Moss Forest (IP, bS)
Ta 1 Bog Forest (bS, IT)
R Rock Lichen (bS, IT)
- 2. RUTLEDGE-PILOT ECODISTRICT**
2 (Mb / Mv) / Ob
R Rock Lichen
Na 1 Moss Forest
Ta 1 Bog Forest (bS, IT)

MB-MID BOREAL ECOREGION

Closed-crown mixedwood forest on fine-textured materials: coniferous forest on granitic rises. Dystric and Eutric Brunisols on well drained sites. Organic Cryosols, Regosols and Gleysols on the poorly drained lows

- 1. EAST ARM ECODISTRICT**
3 (B / Mv) / Lp
R Rock Lichen (IP, bS)
Na 2 Shrub Woodland (bS, IP)
Re 1 Moss Forest (bS, wS)
- 2. TSU-SLAVE ECODISTRICT**
1 (L / Lp)
Fo 1 Shrub Forest (wS, IA, IP)
No 1 Shrub forest (wS, bP)

KEY TO DESCRIPTION OF ECODISTRICTS



- Relief:**
- Level to gently undulating, slope 0-2% approx
 - Undulating to gently rolling; slope 3-9%
 - Rolling to hilly; slope 9-30%

Vegetation: described by combinations of physiognomic terms

- Heath** Dwarf evergreen shrubs (*Ledum*, *Empetrum*, *Vaccinium*, *Arctostaphylos*, *Lolostea*, etc.)
- Lichen** Ground-dwelling large lichens (shelly *Cleodonia*, *Stereocaulon*)
- Rock Lichen** *Saxicolous* (*Parmelia*, *Actinogyra*, *Rhizocarpon*)
- Moss** Feather mosses and those preferring the shaded habitat (*Pleurozium*, *Hylocomium*, *Dicranum*, *Tomenthypnum*, occasional *Sphagnum*)
- Sedge** Grass-like hydric species (*Carex*, *Eriophorum*, *Scirpus*)
- Woodland** Trees scattered in open park-like stands
- Forest** Trees close together, forest floor shaded
- Shrub** Broadleaved deciduous shrubs, medium to tall in height (*Betula*, *Salix*, *Alnus*); combined with Woodland or Forest, denotes a relatively rich, well-watered type
- Bog** Consolidated peatland, dominated by *Sphagnum* species. Deep and residual or shallow and "lumpy"
- Meadow** Wetland with a mucky mineral substratum and with only shallow peat accumulation

Tree Species: symbols are conventional

- bS Black Spruce (*Picea mariana*)
wS White Spruce (*Picea glauca*)
IP Jack pine (*Pinus banksiana*)
IT Larch or Tamarack (*Larix laricina*)
wB White Birch (*Betula papyrifera*)
IA Aspen (*Populus tremuloides*)
bP Black Poplar (*Populus balsamifera*)

ECOREGIONS AND SUBREGIONS

Ecoregions are defined as large areas under the influence of a distinctive macroclimate (i.e., all landscape processes participate in one major regime), as indicated by a distinctive structure of the vegetation and soils on the typical landforms. Our major divisions are recognized by reference to certain physiognomic 'formations' as described and explained in the section on 'Vegetation'. Here, attention is directed to the ecology of boundary and core areas shown on the ecological map.

HIGH SUBARCTIC

The High Subarctic Ecoregion has the appearance from the air of dominance by treeless tundra, characterized by lichens and heaths on the dry uplands and by sedges and mosses on the wet lowlands. A commonly cited boundary for the woodland-to-tundra transition (from Low Subarctic to High Subarctic) is that marked on a NTS map as a dashed line labelled 'Limit of Trees (position approximate)'. The designation is somewhat misleading, for the upright tree form and conifers as shrubs persist far beyond this limit. Therefore, we recognize two boundaries delineating a belt (Forest Tundra) within which the NTS 'Limit of Trees' lies. The first, hereafter called 'treeline', marks the disappearance of trees from morainic ridges; the second marks the virtual disappearance of the tree form, except in particularly favourable local (micro) climates.

Treeline represents a striking break in the patterning of regional vegetation; the change from woodland to tundra on the upland inter-fluves takes place within a short distance and is expressed over a circumpolar range. It parallels no known discontinuities in lithology, surficial geology, or relief. Therefore, it appears to be climatically induced, and most ecologists accept it as such. Supporting this view is its general coincidence with several characteristic terrain features: eroded polygonal peat plateaus, collapsed 'peat cliffs' marking thaw extensions of lake bays, and strongly sorted stone nets in lake shallows.

We accept treeline as a significant ecological boundary, marking a transition from one biogeoclimatic regime to another, from the Low Subarctic Ecoregion to the High Subarctic Ecoregion. The first subregion or zone of the High Subarctic beyond treeline is aptly called Forest Tundra rather than Woodland Tundra because, as in the Low Subarctic, the

trees on slopes and drainages below the open uplands are usually closed-crown. Forest Tundra extends to the limit of the upright tree form, changing there to the second subregion -- Shrub Tundra -- which extends to the limit of trees in shrub or krummholz form (the tree species limit). The entire north and northeast part of the LRMA is Shrub Tundra of the High Subarctic; we recognize no Low Arctic Ecoregion in the study area.

Explanations for the Forest Tundra take both summer and winter climate into account. It is postulated that trees (primarily the black spruce) cannot reproduce sexually beyond a certain latitude-altitude (treeline) where, during the growing season, the environment is inimical to seed set, germination, and growth (Black, 1977). The northern limit of the tree form is set by the unfavourable season where 'phanerophytes' (tree plants whose perennating buds are well above ground level) cannot survive the rigours of cold aerial temperatures, wind, and snow blast. The zone between the favourable season 'tree reproductive limit' to the south and the unfavourable season 'tree form limit' to the north is the Forest Tundra. The continuation of the High Subarctic -- the Shrub Tundra -- is characterized by abundant shrubs (chiefly birch) between the tundra uplands, with scattered low bushy clones of spruce that survive by vegetative reproduction in places where snow accumulation gives protection.

A review of literature pertaining to treeline and tree species limits is beyond the scope of this study. Attention is drawn to only a few key references.

Following the "traditional empirical technique of matching one geographical distribution with another", Hare and Ritchie (1972) pointed out the near coincidence of the Canadian continental zonal vegetation belts in the north with net radiation averaged for the year. Referring to the sharp decrease in energy regime from Boreal woodland to tundra, they argued that vegetation markedly influences macroclimate through its effects on albedo and on surface aerodynamic roughness. However, if the hypothesis of Bryson (1966) is correct that 'Arctic treeline' marks the modal position in summer between maritime polar (rarely maritime tropical) air masses to the south and cold maritime Arctic air masses to the north (terminology of Burns, 1973), then the primary influence must certainly be in the upper atmosphere, modified near the ground by interaction with landform, water bodies, and vegetation. The boundary is climatic and ecological, set by the interacting components of terrain.

A question arises as to the relative significance of the terrain components and factors: can any be singled out as particularly important and biologically limiting? Within the climate complex, attention is usually directed to temperature and to moisture (precipitation and evapotranspiration). The latter is considered to be secondary, for reasons given in the section on 'Climate'. It is the consensus that heat regime, indicated by temperature, is the more significant parameter.

Hustich (1966) reviewed some of the extensive European and American literature relating treeline to summer temperatures, pointing out that a good correlation with isotherms of the warmest month has often been reported. He remarked that "the duration of different growth processes (of the forest-tundra pines) are concentrated in July" and the "July isotherm at the treeline itself must ... be a better indicator than in more southern parts of the boreal region where precipitation comes in as an added influence". In Alaska, Hopkins (1959) found a close correspondence between degree-days above 10°C and major vegetation types. Other examples of thermal parameters matched to northern forest boundaries are potential evapotranspiration (Hare, 1950) and duration in days of the thaw season, i.e., mean air temperature above 0°C (Hare and Ritchie, 1972).

In the Lower Mackenzie Valley area, Black (1977) found a mean summer temperature decrease of about 4°C northward through four ecoregions (on a 135 km transect), or approximately 3°C per 100 km. A linear regression between mean June temperatures and degree-days suggested a northward decrease of 90 degree-days for each degree of latitude. Based on several years of summer weather measurements, Black reported the 1200 degree-day (base 0°C) isoline to be a significant boundary; north of it, in Forest Tundra, the black spruce failed to reproduce sexually or its seeds failed to germinate.

Figure 2 shows isolines of the temperature-related parameters: growing degree-days and effective growing season (from Findlay and Treidl, 1975). The data are too generalized to be very useful in testing proposed regional boundaries. However, the southwest to northeast gradient is indicated and the Forest Tundra subregion is approximately delimited by the 600 to 700 degree-day lines.

LOW SUBARCTIC

The Low Subarctic Ecoregion is characterized

by open woodlands, primarily of black spruce, with a ground cover of reflectant lichens (chiefly Cladina, Cladonia, and Stereocaulon species) through which dwarf shrubs are interspersed. The boundary with the High Subarctic is placed where trees disappear from the well-drained uplands (treeline as previously defined). The boundary with the High Boreal resembles an inverted 'L' with the angle enclosing the East Arm, marking the change from Lichen Woodland to closed Coniferous Forest (the 'Northern Forest Line' of Hare and Ritchie, 1972).

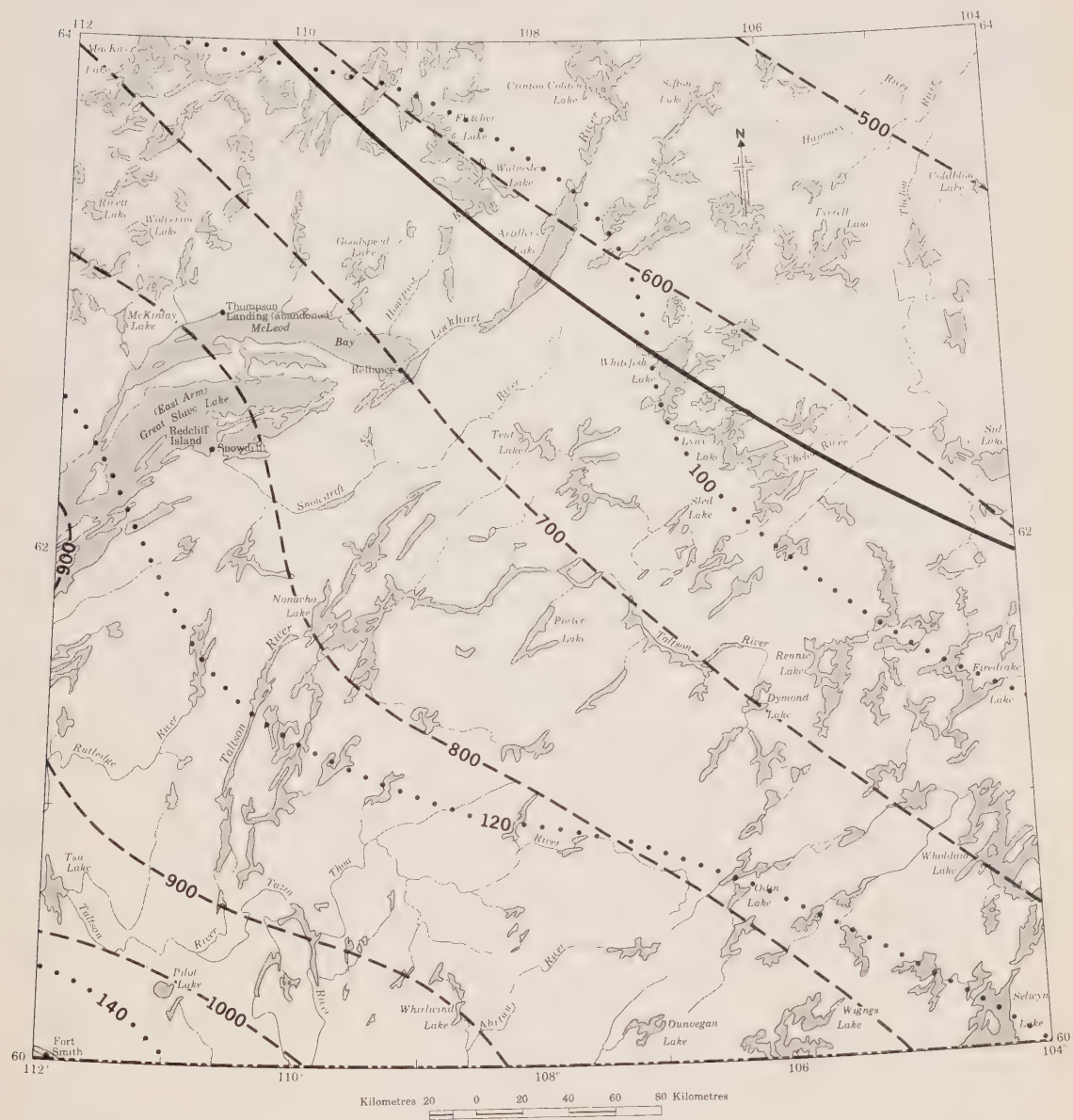
The north-south leg of the latter boundary runs from the Snowdrift River at 62°30' latitude, 109° longitude to Saskatchewan's north border at 60° latitude, 108° longitude. Here, compared to treeline, a different constellation of factors operates. Study of photo-mosaics at 1:60,000, and of LANDSAT imagery, shows a change in surficial materials and landforms. Eastward the drift tends to be deep and streamlined, characterized by extensive drumlin fields and flutings that are divided east-west every 16-20 km by massive esker trains. Westward the drift is shallow and controlled by the underlying bedrock lineations; streamlined forms are few and eskers are small (see Figure 11). The generalized map of surficial materials in the National Atlas of Canada (anon. 1965, p. 37-38) also shows the change at about 108° longitude from predominantly unconsolidated materials on the east to bedrock exposures on the west. Furthermore, the boundary is near the 400 m contour above which Lichen Woodland is prominent; perhaps the strongest expression of the type is on the deep drumlinized till of the Abitau upland where altitudes are above 500 m.

Retreat of the last glacier from the LRMA proceeded from west to east, and the western Low Subarctic boundary parallels the probable position of the ice front about 8000 BP (Bryson et al., 1969), possibly contemporaneous with the Cochrane readvance to the Cockburn moraine south of James Bay. There are no well-marked end moraines in the LRMA, and evidence of glacier readvances or stades may be expressed as changes in depositional and erosional glacial landforms. As there is no detectable lithologic discontinuity it may be that the physiographic-vegetational boundary relates to a significant late Pleistocene event.

This boundary, like the others, is presumed to carry with it a change in climatic regime. This is not due, however, to air-mass differences (as at treeline), but to changes in surficial features across an altitudinal

Figure 2: Temperature-related indices for the LRMA (redrawn from Findlay and Treidl, 1975)

Growing Degree-Days (base 5.6°C, 1953-67 averages) are shown by dashed lines; Effective Growing Season in days (1950-59 averages) is shown by dotted lines. The solid line through Whitefish Lake marks the southern limit of Continuous Permafrost according to Brown (1967). See also Figure 16.



gradient imposing a division on what would otherwise be one regional regime.

HIGH BOREAL AND MID BOREAL

The Boreal is distinguished from the Low Subarctic by the prevalence of closed-crown forests. We have made a division into High and Mid Boreal ecoregions, marked by the sharp geological transition from the western lowlands (Slave River plain and Great Slave Lake basin) to the Precambrian uplands. Changes in vegetation and soils are correspondingly distinct, reflecting the break at about the 300 m contour between weakly calcareous alluvial-lacustrine materials within the basin of Glacial Lake McConnell and acidic till or outwash materials expressing strong bedrock control on the Shield.

The Mid Boreal to High Boreal boundary shows a sharp ecotone change in vegetation. The relatively fertile soils of the Slave River Lowlands support good mixedwood forests on moist sites, where pure aspen-poplar stands follow fire, and extensive fens and marshes on wet sites. This recognizable pattern is replaced, where the Shield bedrock rises, by pine-spruce conifer stands and *Sphagnum* bogs. The boundary is reasonably well defined by relief which imposes the climatic control and which has influenced surficial deposits, soils, and biota.

The other regional boundaries around Great

Slave Lake are also clearly related to relief. At the McDonald Fault there is a sharp drop from granitic uplands to the sedimentary basin and a concurrent change to more diverse soils, forests, and flora. Relationships to the Slave River Lowlands are found in the scattered presence of *Populus* species and in the prominence of well-grown white spruce forests.

On the north side of the East Arm of Great Slave Lake, the transition from Mid and High Boreal to Low Subarctic and then to High Subarctic is telescoped into a relatively short distance. Closed-crown forests on the southerly dipping rocks of the north shore change to open woodland on the broad plateaus 200-300 m above lake level. Northward, within 40 km, tundra dominates the till-over-bedrock rises where presumably the summer influence of the Arctic front is expressed. Thus the physiognomic change from Closed Forest to Open Woodland to Forest Tundra and Shrub Tundra appears to be the result of marked changes in relief and air mass climate. However, fire has blurred the pattern and it is difficult to tell whether the extensive rock 'barrens' and shrub-covered till areas are the direct result of rigorous climate. It is significant that over large parts of the Boreal to High Subarctic ecotone, no typical Low-Subarctic Lichen Woodland appears. Dashed lines on our map around the East Arm indicate doubts as to the zonation.

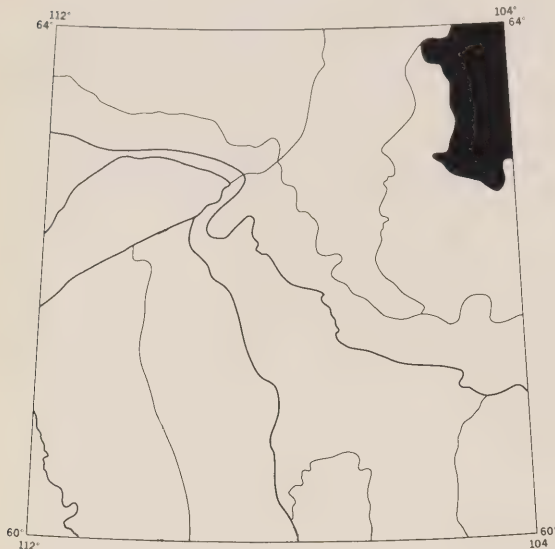
SECTION F
ECODISTRICTS

ECODISTRICTS

Ecodistricts are subdivisions of ecoregions and subregions where, due to the influences of altitude (relief) and/or geological substratum, the climatic regime and landscape processes differ substantially from adjacent lands. Reliance on relief and geology to discriminate ecodistricts also implies that waterbody forms will be characteristic.

Fourteen ecodistricts are distinguished in the LRMA. Following their listing below, a short description of each is given.

<u>Ecoregion</u>	<u>Ecodistrict</u>	<u>Map Symbol</u>
High Subarctic		
Shrub Tundra	1. Thelon	HS _{ST} ¹
	2. Tyrrell-Sid	HS _{ST} ²
	3. Sifton-Whitefish	HS _{ST} ³
	4. MacKay-Walmsley	HS _{ST} ⁴
Forest Tundra	5. Tent-Firedrake	HS _{FT} ⁵
	6. Rivett-Goodspeed	HS _{FT} ⁶
Low Subarctic		
	1. Wholdaia-Selwyn	LS1
	2. Porter-Wignes	LS2
	3. Abitau-Dunvegan	LS3
	4. McKinlay	LS4
High Boreal		
	1. Nonacho-Whirlwind	HB1
	2. Rutledge-Pilot	HB2
Mid Boreal		
	1. East Arm	MB1
	2. Tsu-Slave	MB2

THELON ECODISTRICT(High Subarctic Shrub Tundra; HS_{ST}¹)

This is the lowest lying of the LRMA ecodistricts, with some parts of the plain below 100 m altitude. It lies within the inundation basin of Glacial Lake Thelon and is characterized by a reddish till (derived from Dubawnt sandstone) on which the Coldblow Lake soil association has developed. In the 'forest islands' of spruce and tamarack along the Thelon River, there is an intermixing of Boreal and Arctic species; on the frost-patterned uplands, the Arctic element is more pronounced. Muskoxen are not uncommon in this and the following ecodistrict.

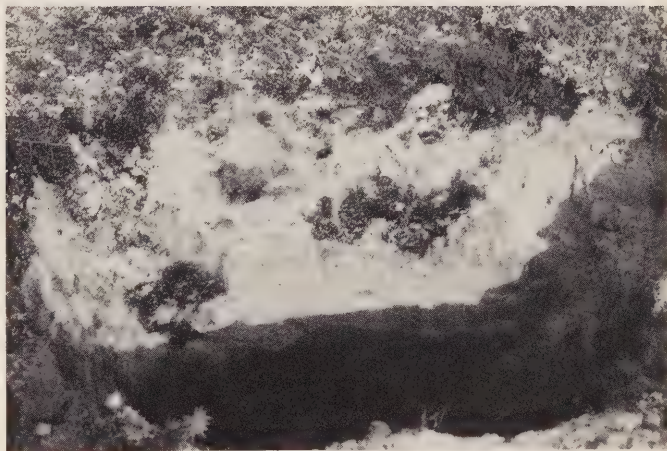
Extensive area of mud boils, developed on silty soils; the centers of the boils are sparsely vegetated, while the depressed rims are vegetated by heaths and lichens; in the upper right corner, a drainage channel supports thick Betula glandulosa and Picea mariana.



In the foreground, Heath-Lichen-Grass vegetation on a dry site; in the central strip, a mosaic of Sedge Meadow and Shrub (Betula glandulosa) Thicket, occupying a slight wet depression; in the right foreground, frost-heaved boulders.

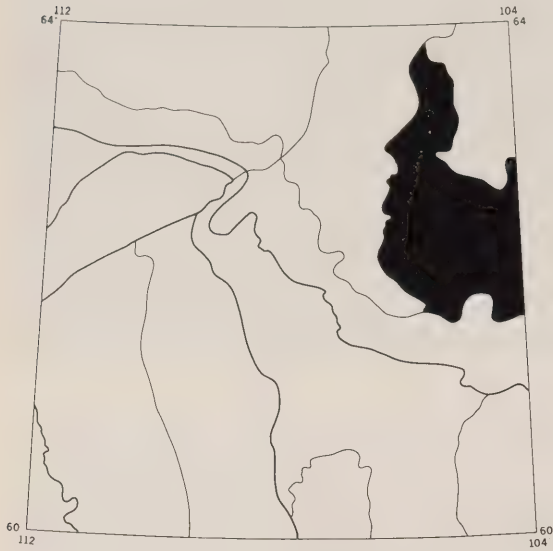


Eluviated Dystric Brunisol, cryoturbic phase, associate of the Coldblow Lake 1 soil association developed on glacial till; intrusions of the organic layer into the mineral material have resulted from cryoturbation; profile P41 (62°52'N, 104°20'W).



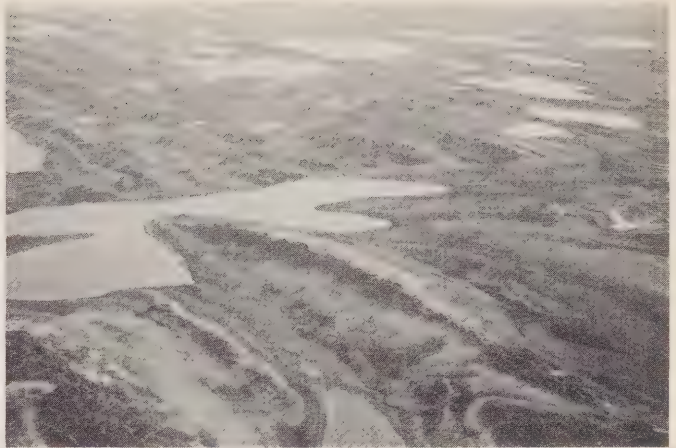
TYRRELL-SID ECODISTRICT

(High Subarctic Shrub Tundra; HS_{ST}2)



Higher than the adjacent Thelon Ecodistrict, this area was also influenced by Glacial Lake Thelon as indicated by strandlines and erosional features on the frost-patterned uplands. A characteristic grey till derived from sandstone supports the Lynx Lake soil association. In the northern part, the frost-patterned moraine landforms are 'blackened' on their crests by the wiry Cornicularia and Alectoria lichens, while eskers and extensive outwash plains support scattered groves of white spruce.

Streamlined drumlins and flutings are common in ecodistrict HS_{ST}²; these drumlinized ridges are intermediate between drumlins and flutings; the most exposed ridges, frequently polygonally patterned, are bare or sparsely covered with Grass-Lichen; upper slopes are dominated by thick black mats of Cornicularia divergens, particularly on north aspects, while mid slopes bear yellow Cetraria Lichen-Heath or sparse Birch-Heath; lowland sites are Sedge Meadow or eroded polygonal peat plateaus (high center peat polygons).



Although there is much bare ground on this drumlin crest at the south end of Tyrrell Lake, thick mats of Cornicularia divergens and Arctostaphylos alpina occur locally.



Orthic Dystric Brunisol, cryoturbic phase, associate of the Lynx Lake 1 soil association, developed on till; this soil, associated with a nonsorted circle, is strongly cryoturbated and thixotropic; mechanical disturbance causes these thixotropic soils to become fluid and soil flow occurs, as is shown on the left side of the photo; profile DP3 (62°23'N, 106°05'W).



SIFTON-WHITEFISH ECODISTRICT

(High Subarctic Shrub Tundra; HS_{ST}³)



This ecodistrict is covered by a coarse till derived from granitic and gneissic rocks (Wolverine Lake soils), in contrast with the Thelon and Tyrrell-Sid ecodistricts that have their distinctive sandstone-derived tills. Two broad landscapes (subdistricts) can be distinguished. The northern half is characterized by strong structural trending of the bedrock and a thin cover of bouldery till. Here, the flora exhibits a number of Arctic elements while tree species are virtually non-existent, even on the coarse outwash materials that elsewhere in the High Subarctic harbour patches of white spruce. The southern half carries a much thicker covering of till which is commonly drumlinized. In this area, tree species occur along sheltered slopes and in drainages, but the prominent vegetation on the frost-patterned morainic rises is Heath-Lichen tundra.

Extremely bouldery till occurs locally throughout the LRMA; at this site, near treeline, scattered clones of Picea mariana dot the tundra landscape; Rock Lichen covers most of the boulders, while Heath-Lichen occupies the ground between.

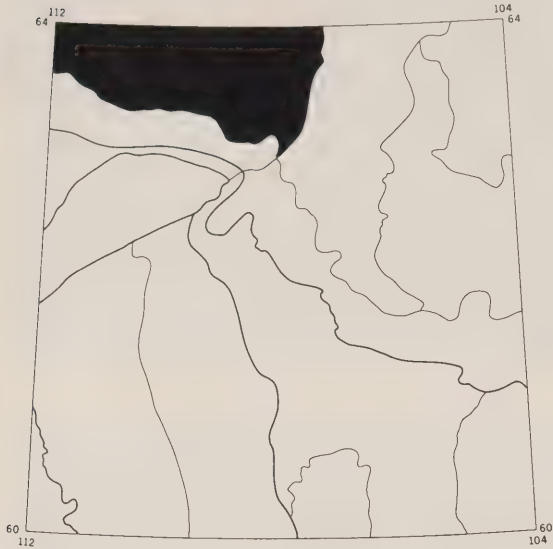


Betula glandulosa and Arctostaphylos alpina heath on patterned ground (nonsorted steps and circles); these patterned ground types have developed on till and are associated with the Coldblow Lake, Lynx Lake, and Wolverine Lake soil associations.



Orthic Dystric Brunisol, cryoturbic phase, associate of the Wolverine Lake 1 soil association, developed on deep till; the organic-rich intrusion on the upper part of the photograph has resulted from cryoturbation; profile P37 (63°18'N, 111°52'W).



MACKAY-WALMSLEY ECODISTRICT(High Subarctic Shrub Tundra; HS_{ST}⁴)

The northwest corner, a section of the Bear-Slave Upland physiographic unit, is a low-relief peneplain at about 400 m altitude. Bedrock is prominent, overlain in most parts by a thin veneer of bouldery till, and supporting a maze of unoriented lakes covering 30-40% of the surface. Deeper till areas are patterned with mud boils and nonsorted stripes. Small patches of black spruce grow in protected drainages and along lakeshores throughout the area.

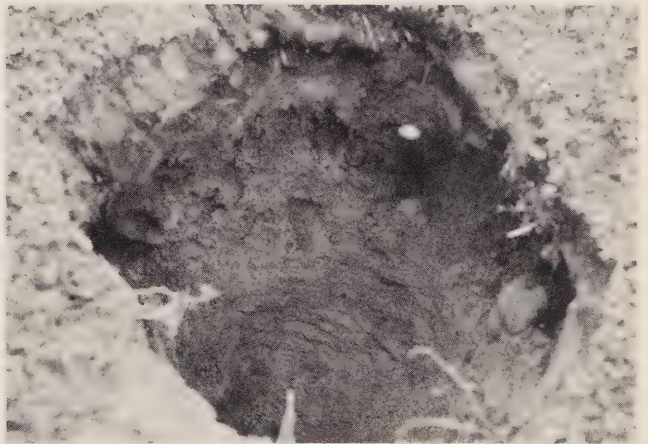
Shrub Tundra (Betula glandulosa, heath species, and lichens) with stunted Picea mariana in gully.



Bouldery outwash area in ecodistrict HS_{ST}⁴.

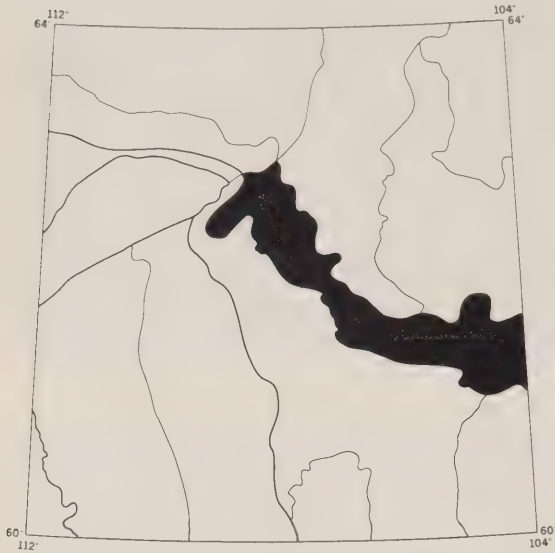


Eluviated Dystric Brunisol of the Hoarfrost River 1 soil association, developed on ice contact and fluvial materials; Vaccinium vitis-idaea on the surface.



TENT-FIREDRAKE ECODISTRICT

(High Subarctic Forest Tundra; HS_{FT}⁵)



This ecodistrict is one of two recognized within the High Subarctic Forest Tundra ecotone, the other being the Rivett-Goodspeed. The two are separated where the Back Lowland wedges out at lower Artillery Lake and the Lockhart River. South and east of the division, the ecotone cuts across typical LRMA terrain -- a series of large esker trains and till-over-bedrock interfluvies, interrupted by major lakes that lie near the 400 m contour. Till uplands are characterized by Heath-Lichen vegetation, often yellowish on the rises due to the presence of *Cetraria*, *Cladonia*, and *Cladonia* lichens, with trees restricted to slopes and drainages. Patterned ground is occasionally visible as faint polygons on rounded moraine ridges. The most striking feature is the prevalence of treeless peat plateaus with polygonally patterned surfaces. Many are eroding due to recession of the ice wedges in the fissures, exposing dark brown peat along the margins of the polygons as well as on their high-centered surfaces.

In the Forest Tundra ecotone, trees are restricted to topographically favourable positions, and upland sites are largely treeless; lowland vegetation is Heath-Lichen Bog, often with much Betula glandulosa on polygonal peat plateaus, many of which are eroded.



Characteristic Heath-Lichen vegetation occupies the north slope of most eskers in the High Subarctic; clumps of Betula glandulosa on all slope positions, tall white spruce at the foot of the esker, small straggly black spruce near the esker crest (upper left), and Lichen Woodland/bare sand complex with low relief outwash in the distance.

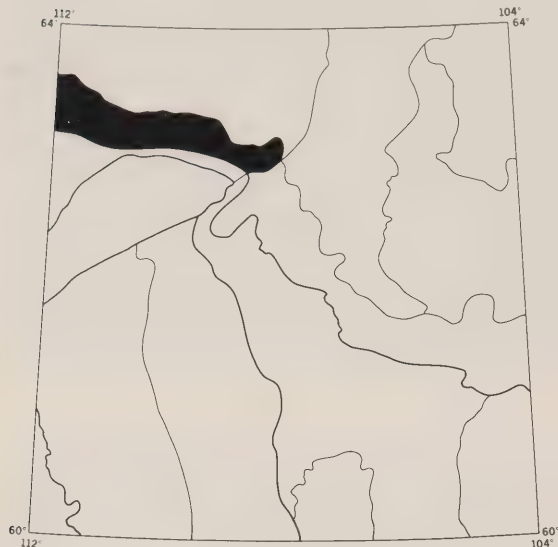


Eluviated Dystric Brunisol, peaty phase, of the Wolverine Lake soil association, developed on till; vegetative cover of Picea mariana and Heath-Lichen Bog; profile from near Eileen Lake.



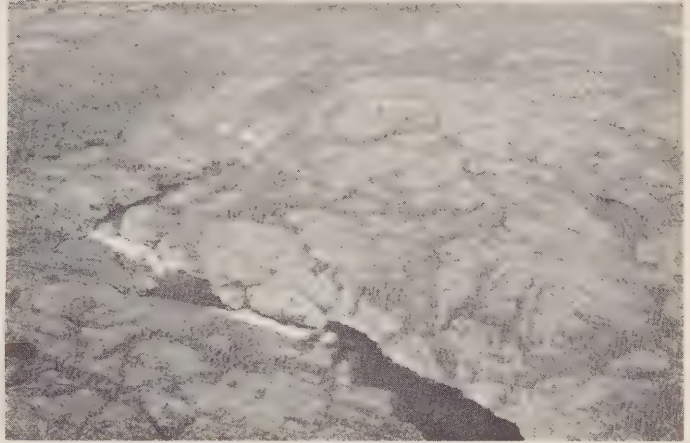
RIVETT-GOODSPEED ECODISTRICT

(High Subarctic Forest Tundra; HS_{FT}⁶)



The Forest Tundra ecotone along the north side of the Great Slave Lake coincides with this ecodistrict. Glacial drift is shallower than in the related Tent-Firedrake Ecodistrict, with the result that bedrock is more prominent; exposures are particularly rugged in the eastern half. Rock-rimmed lakes are numerous, though relatively small and without any particular orientation. The structure of the vegetation is characteristically Forest Tundra, with trees restricted to the topographic lows and with birch, heaths, and lichens on the tundra rises. Polygonal peat plateaus are not prominent features. In the western half, where organic terrain occupies broad, gently sloping surfaces, a 'striped bog-and-fen complex' somewhat suggestive of a string bog is common. This peatland type often terminates downslope in an eroding polygonal peat plateau, suggesting its origin in the disintegration of permafrost in formerly more extensive peat plateaus.

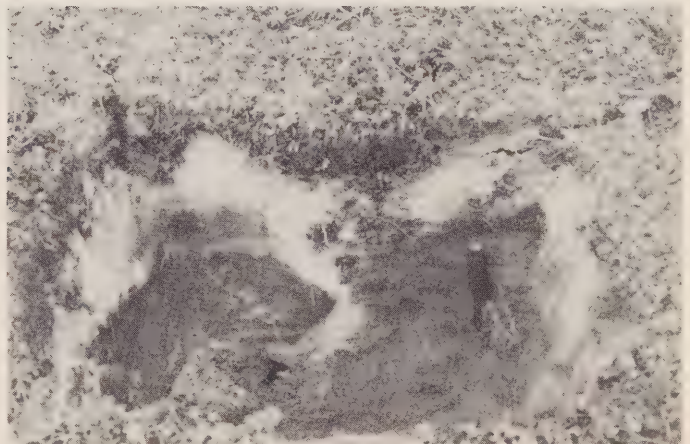
Where exposed bedrock dominates the landscape near treeline, vegetation structure is controlled by lineations in the bedrock; trees are Picea glauca and P. mariana; Pinus banksiana is absent; the Lockhart River, between Artillery Lake and the East Arm of Great Slave Lake.



Forest Tundra, with shrubs dominating the uplands and trees (Picea mariana) lining the lakeshore.

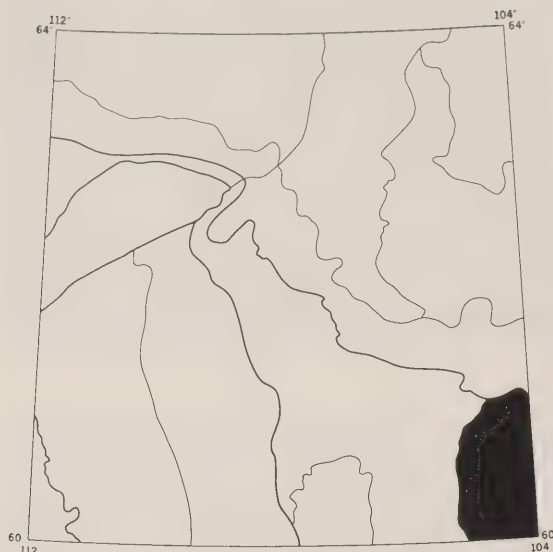


Eluviated Dystric Brunisol, cryoturbic phase, of the Wolverine Lake soil association, developed on till; Ae horizon tonguing in fissure.



WHOLDAIA-SELWYN ECODISTRICT

(Low Subarctic; LSl)



This ecodistrict lies mostly below the 400 m contour, coinciding generally with the inundation basin of Glacial Lake Hyper-Dubawnt whose strandlines are visible on some of the higher till uplands. The bedrock is mostly gneiss and schist, mantled with bouldery till (Porter Lake soils) and occasional outwash materials (Odin Lake soils) that support very open Lichen Woodland on the well-drained sites. Lowland organic terrain (Dymond Lake soils) is extensive, the typical expression being treeless polygonal peat plateaus that frequently show signs of erosion. Numerous large lakes, shallow and boulder-studded, show a tendency to a northeast-southwest orientation.

Typical Low Subarctic terrain with Lichen Woodland on streamlined till (upper left), a treeless peat plateau with Heath-Lichen Bog vegetation occupying a broad toe position, and Moss-Lichen Woodland along the lake-shore; Sedge Fen occupies poorly drained depressions.



In the foreground, treeless peat plateau dominated by hummocky Heath-Lichen Bog, with clonal Picea mariana growing at the edge of the plateau above a sedge-rich Fen; the hummocky peat plateau continues beyond the Fen, with Bog Woodland in the background.



Eluviated Dystric Brunisol associate of the Porter Lake 1 soil association, developed on deep till; sparse vegetative cover (only a few mosses and some low shrubs) due to a recent forest fire; profile P4 (61°47'N, 107°52'W).



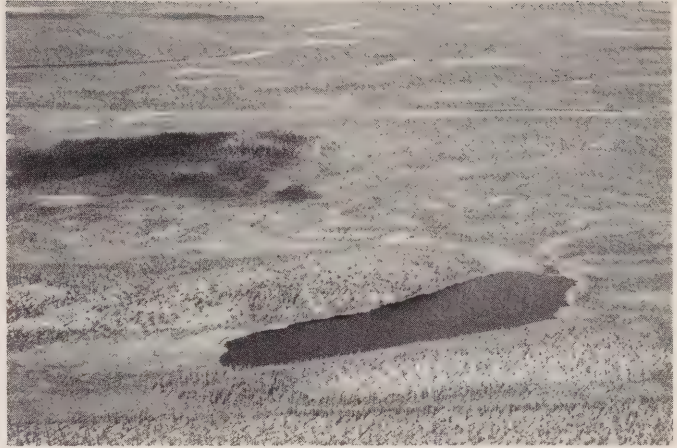
PORTER-WIGNES ECODISTRICT

(Low Subarctic; LS2)



This largest ecodistrict of the LRMA is roughly triangular in shape, extending from a broad base on the 60° parallel to an apex on the Snowdrift River at 61°30' latitude. The western border marks the transition from Low Subarctic (open woodland) to High Boreal (closed-crown forest). The east boundary follows treeline to the presumed boundary of Glacial Lake Hyper-Dubawnt, then southward to the Saskatchewan border. Eskers are very common throughout the morainic landscape, which is dominated by drumlins in the southeast adjacent to the higher lands of the Abitau-Dunvegan Ecodistrict. Open Lichen Woodland is the prevalent vegetation on both till and outwash; in the drumlinized areas, however, both bog and fen often comprise 40-50% of the landscape cover. In the southeast, the peat plateaus are treeless, often with polygonally patterned surfaces.

A typical Low Subarctic landscape, with Lichen Woodland on till uplands, Heath-Lichen Bog on peat plateaus, and Sedge Fen on wetter sites.



Open Lichen Woodland on coarse drift, characterized by Picea mariana and yellowish or whitish lichens of the genera Cladina, Cladonia, and Stereocaulon; heath mats encircle the bases of the trees, excluding most shade-intolerant lichens; in old age, the trees tend to reproduce vegetatively by layering where lower branches touch the ground; slow decay accounts for the abundance of fire-killed and/or wind-tipped deadwood.

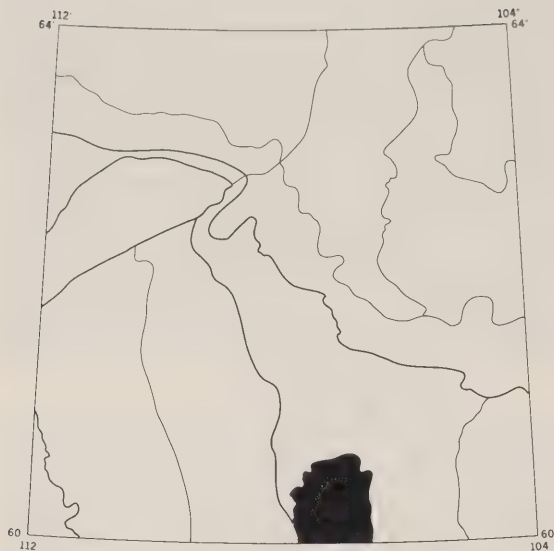


Eluviated Dystric Brunisol associate of the Porter Lake 1 soil association developed on deep till; typical dense lichen cover characteristic of soils associated with open woodland; profile P74 (60°22'N, 107°20'W).



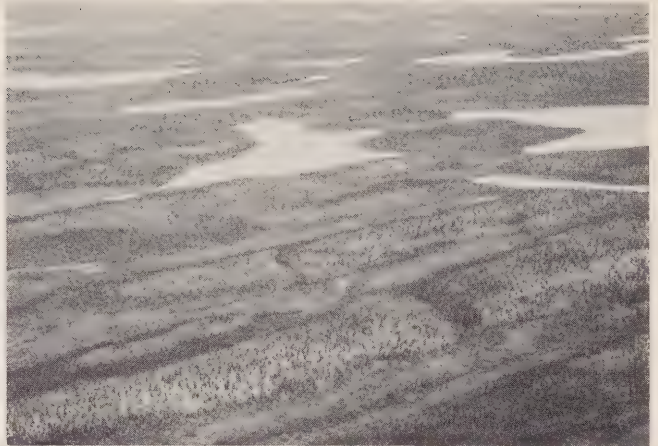
ABITAU-DUNVEGAN ECODISTRICT

(Low Subarctic; LS3)



This ecodistrict is the highest in the LRMA; its surface lies mostly about the 500 m contour and centrally rises close to 600 m. The till cover is deep and streamlined; coarse stratified drift landforms are common, and there are only sporadic outcroppings of bedrock. On the well-drained moraine uplands, Lichen Woodland is strongly developed, with Stereocaulon lichens particularly prominent in the reflectant ground cover. Black spruce, jack pine, and white birch dominate the woodland mosaic, while extensive peat plateaus mantle the lowlands.

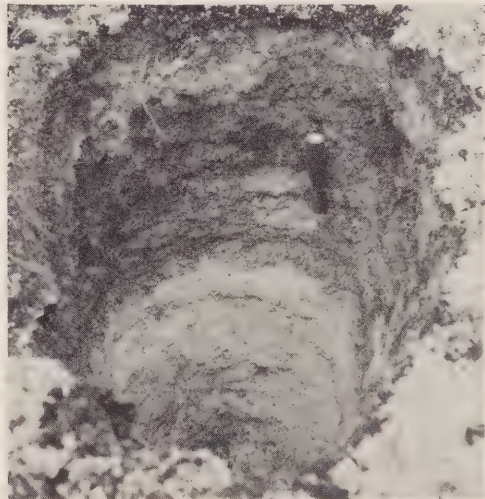
Open Lichen Woodland vegetative cover on drumlinized till; Bog and Fen complex is typical in poorly drained lowlands between the drumlins.



Lichen woodland terrain on drumlinized till hillcrests, characterized by Cladina mitis (on the left) and Stereocaulon paschale along with the low- to medium-height shrub Vaccinium uliginosum; Picea mariana in the background.

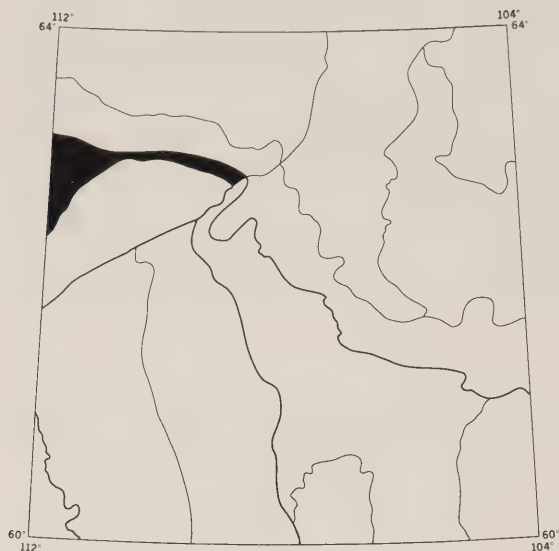


Porter Lake 1 soil association, Orthic Dystric Brunisol on siliceous till.



McKINLAY ECODISTRICT

(Low Subarctic; LS4)



As in the other ecodistricts north of Great Slave Lake, the stony drift is thin over granitic bedrock. Altitudes vary from 300 m (south) to 400 m (north) and the local relief is low. Unoriented lakes are abundant. There are remarkable stretches of organic terrain in a striped bog-and-fen pattern in some of the broad topographic lows. On the uplands, a dense cover of broadleaf shrubs (mostly dwarf and river birches) probably reflects the recent influence of fires. Eastward, the open woodland type fades away on the bedrock plateaus bordering Great Slave Lake and the tentative boundary of the ecodistrict is indicated on the map with a dashed line.

Terrain north of Great Slave Lake in ecodistrict LS4; mixed Lichen Woodland and peatlands.



Eroded rill in a peat plateau, dominated by Eriophorum vaginatum and Sphagnum fuscum.

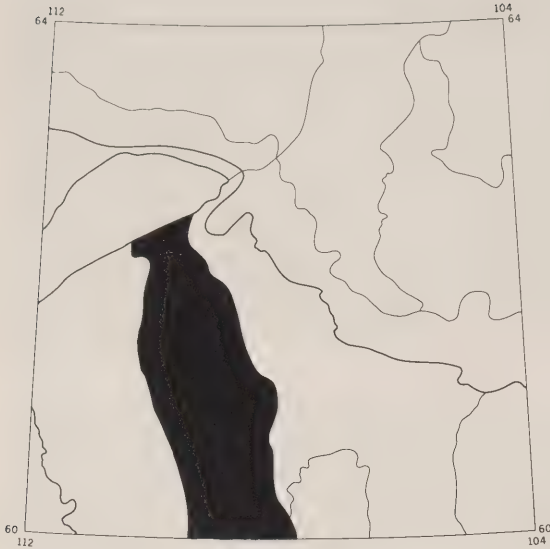


Odin Lake 1 soil association, Eluviated Dystric Brunisol on stratified sand and gravel (ice contact and fluvial materials).



NONACHO-WHIRLWIND ECODISTRICT

(High Boreal; HB1)

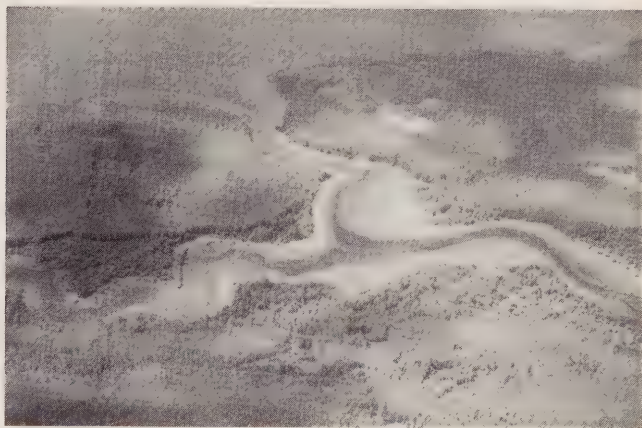


This ecodistrict is roughly a north-south strip extending from the McDonald Fault to the Saskatchewan border. The east margin is approximately at 400 m and there is a gradual decline westward. Strong bedrock control of the drift cover (supporting the Nonacho Lake 2 soil association) is particularly apparent in the north where the percentage of surface water is also high (20-30%). Eskers and outwash landforms are reduced in extent compared to the neighboring terrain to the east. The prominent vegetation is black spruce forest on both uplands and lowlands.

Powder Lake, about 60 km south of Nonacho Lake in ecodistrict HBI; Betula (lighter tones) crowns scattered through Picea mariana forest on till over bedrock.



Deep alluvium deposits on the Lower Snowdrift River support a rich, dense vegetative cover, broken only by occasional bedrock outcrops; Rock Lichen Woodland, Moss Forest, Shrub Thicket, and Sedge Fen communities are present.

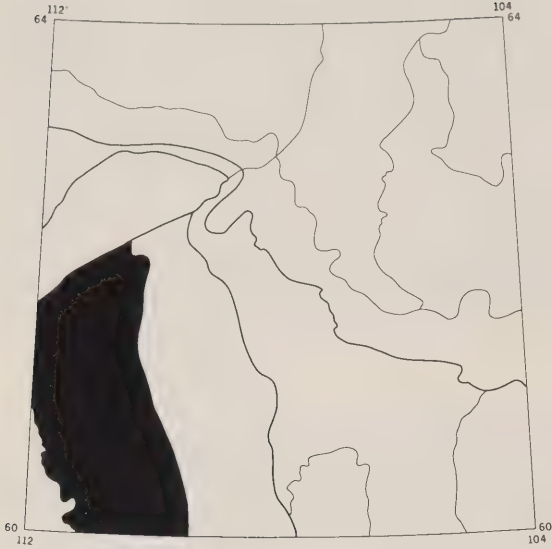


Characteristic Rock Lichen Woodland; most exposed granitic bedrock is covered by crustose lichens, although clumps of fruticose Cladonia and Cladonia lichens are prominent; Pinus banksiana and Picea mariana grow in bedrock crevices where soil development is sufficient.



RUTLEDGE-PILOT ECODISTRICT

(High Boreal; HB2)



This westernmost High Boreal ecodistrict coincides with bedrock-controlled uplands that carry only a thin veneer of stony till. Outwash landforms (Snowdrift River soils) are relatively rare. The east boundary, at about 350 m, is marked in the south by a sinuous band of metamorphic rock ridges paralleling the Taltson River. The west boundary, at about 250 m, is placed at the line where postglacial inundation affected the bedrock lows, creating a more fertile substratum and a major change in soils. The surface-dry upland terrain of the ecodistrict is very susceptible to lightning fires; even-aged forests of jack pine are therefore prominent, along with the ubiquitous black spruce.

Shrub-Herb Forest of Populus tremuloides occupies the low glaciolacustrine rise to the left; wetlands in the right-center are a mosaic of Marshes and Fens, grassy or shrubby, with Picea glauca on the slightly higher margins.

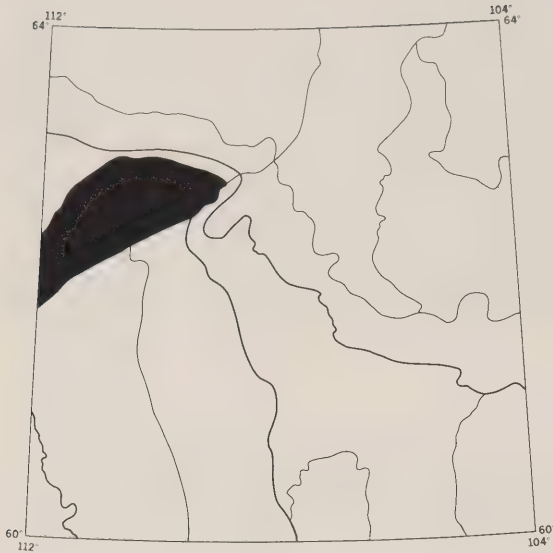


McDonald Fault here marks the boundary between the Shield Upland on the left (ecodistrict HB2) and the basin of the East Arm of Great Slave Lake (ecodistrict MB1); the upland is bedrock dominated and vegetation is primarily Rock Lichen Woodland.



EAST ARM ECODISTRICT

(Mid Boreal; MB1)



The East Arm forms a distinct physiographic ecodistrict rimmed by a crescent of highlands on the north and the straight lineation of the McDonald Fault on the south. The Great Slave Lake basin was inundated to about the 300 m level postglacially, producing clayey soils (Redcliff Island soil association) at the margins of the lake. The added influence of an ameliorated climate, due to proximity of the large water body, has resulted in a much more favourable environment than on surrounding terrain. The rock ridges and plateaus that rise above the lake are bare or thinly till-covered and support open spruce-jack pine stands, the latter species reaching its northern limit within the area. The lowland mineral soils, though frost-stirred, carry a relatively rich Boreal flora.

McDonald Fault with ecodistrict MBI on the right (below the scarp); Picea mariana dominates on shallow peatland; lacustrine clays, often capped with peat, occur in low-lying areas; vegetation is unique for the LRMA with many species characteristic of the southern Boreal Forest; the northern margin of ecodistrict HB2 is on the left (above the scarp).



Kluziai Island in the East Arm of Great Slave Lake, near Thompson Landing; Picea glauca and Betula papyrifera on lakeshore gravelly terrace; in background, Picea mariana on peatland and on till over bedrock.

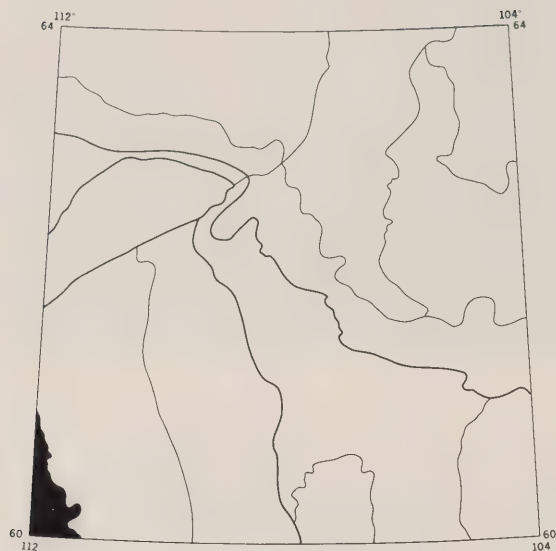


Redcliff Island 1 soil association, an Orthic Turbic Cryosol; soil on lacustrine sediments at Fairbairn Lake.



TSU-SLAVE ECODISTRICT

(Mid Boreal; MB2)



The Slave River Lowlands lie slightly below the 200 m contour. Occasional bedrock ridges rise above the fluvial lacustrine plain, particularly on the east side, though most of the ecodistrict is covered with fine postglacial sediments (Fort Smith soil association). Mixedwood forest of white spruce and aspen occupies well-drained sites, with jack pine on sand ridges and terraces. Lowlands are extensive, bearing willow-sedge fens and marshes. There is more fen peatland than in the other ecodistricts and hence less permafrost terrain.

Slave River lowlands; bog and fen complex on low-lying glaciolacustrine sediments.



Slave River near Fort Smith; mixed-woods (Populus tremuloides and Picea glauca) on glaciolacustrine sediments.



Tsu Lake, about 80 km north of Fort Smith; Picea glauca forest, on glaciolacustrine sediments; rock outcrop on the right, generally characterized by Pinus banksiana in ecodistrict MB2.



SECTION G

ECOSECTIONS: LAND-SOIL-VEGETATION RELATIONSHIPS

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Ecosections are the areal units of which ecodistricts and ecoregions are composed; they correspond to the biophysical 'land systems' of earlier reports. Ecosections are here defined as morphogenetic units that express particular depositional-erosional processes but that also have present-day functional significance. The entire LRMA was glaciated; therefore, most of the ecosections are conceived as patterns of glacial landforms such as eskers-and-outwash trains, thin till veneer on bedrock outcrops, streamlined moraine (drumlin fields), and peat plateaus. Ecosections of postglacial origin are based on fluvial lacustrine and aeolian landform patterns.

Such landscape 'units' are ecologically and geomorphologically significant. Through their influences on local climate and on moisture regime they carry along on their surfaces the appropriate patterns of biota and soils. Thus they are 'catenas' of sites and habitats, 'associations' of communities, and soil series.

Ecosections of the LRMA have not been mapped in this report because of scale problems in a large area, a lack of mosaics for the northern portion, and poor quality of some of the 1:60,000 photo coverage. Instead, generalized profile sketches are presented to illustrate the common catenary relationships of vegetation, soils, and landforms for ecosection patterns in the High Subarctic, Low Subarctic, and Boreal ecoregions. Each profile figure is accompanied by a brief description of the components of the landscape ecosystems.

HIGH SUBARCTIC

Landscape patterns typical of the major terrain areas in the High Subarctic are shown diagrammatically in Figure 3. There are of course a number of variations on the main theme.

Till Landforms: In the High Subarctic, a wide variety of till landforms is displayed, ranging from extensive ground moraine plains to ice-moulded features such as drumlins and flutings, and from extremely bouldery sites such as ribbed moraine and ablation moraine to landscapes with few surface stones. Additionally, the thickness of the till mantle may range from several centimeters to several meters over the underlying bedrock.

Three soil associations encompass the glacial

tills of the ecoregion: the Coldblow Lake association is derived from red or brown sandstones, the Lynx Lake association from white-to-buff sandstones, and the Wolverine Lake association mainly from granitic rock. The latter association is prevalent in the north-central and northwestern portions of the LRMA and has its counterparts in several other districts.

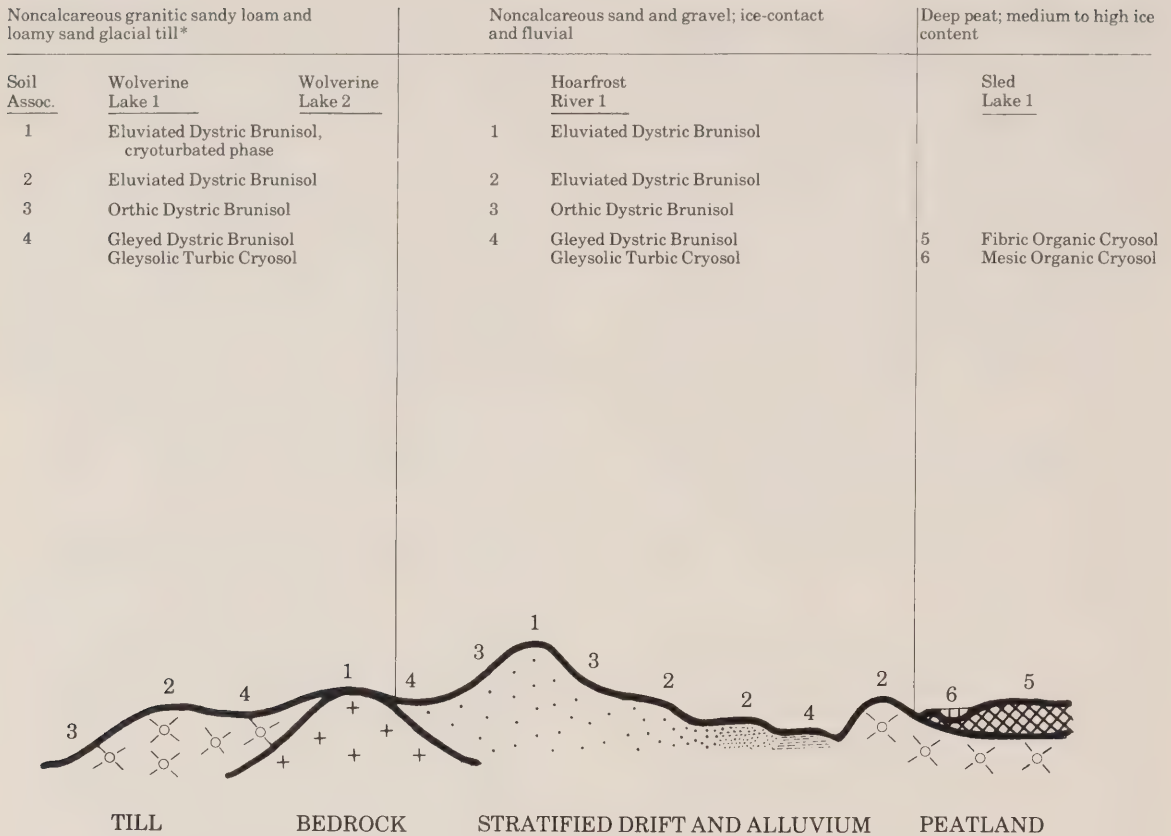
All the till soil associations in the High Subarctic are sandy loam to loamy sand in texture. The common soil on the well-drained site is the Eluviated Dystric Brunisol, often cryoturbated where bedrock is close to the surface. Downslope the catenary members are Orthic Dystric and Gleyed Dystric Brunisols. Shallow peats on lower slopes overlie Gleyed Turbic Cryosols with some segregation of ice crystals, veins, and lenses. However, in general, the ice content is low, and patterned ground where it occurs is in the form of nonsorted circles.

The vegetations on the three tills appear to be similar, apparently reflecting drainage rather than parent material. The generalized vegetation type is Heath-Lichen with abundant dwarf birch (*Betula glandulosa*), dominated by such species as *Empetrum nigrum*, *Ledum decumbens*, *Vaccinium vitis-idaea*, *Cetraria cucullata*, *Cetraria nivalis*, *Cladonia mitis*, *Cladonia amaurocraea*, and mosses of the genus *Polytrichum*. Within the Forest Tundra ecotone, additional important species are *Loiseleuria procumbens*, *Alectoria ochroleuca*, *Cladonia uncialis*, and *Stereocaulon paschale*. Beyond treeline, *Vaccinium uliginosum*, *Arctostaphylos alpina*, *Alectoria nitidula*, and *Cornicularia divergens* are also dominants. Shifts in the relative dominance of the above species result in variants of the 'standard' Heath-Lichen vegetation type.

Drumlins and flutings show slight differences in vegetation according to aspect. Within the Forest Tundra, south slopes of drumlins are dominated by Shrub-Heath vegetation; drumlin crests are similar but with greater amounts of exposed ground. North slopes lack the shrub cover of dwarf birch and are dominated by heaths and lichens. Trees often occupy the lower slopes.

The drumlin catenas are somewhat different northward in the Shrub Tundra. Dwarf birch dominates on south slopes but it is often absent from the crests where wind activity is intense. North slopes continue to be typified by heaths and lichens. Black mats of the lichen *Cornicularia divergens* assume 50-75% cover, often extending to the crests where presumably the wiry growth form allows

Figure 3: High Subarctic: Landform-Soil-Vegetation Catenas



Drainage Classes	Symbol	Vegetation
Excessively drained knolls	1	Rock Lichen and Lichen-Grass
Well-drained flats and convexities	2	Heath-Lichen-Grass
Well-drained side slopes	3	{ Shrub-Heath { Heath-Lichen
- south aspect - north aspect		
Imperfectly drained slopes	4	Heath-Sedge-Moss
Poorly drained flats and concavities	5	Heath Bog (peat polygons)
Saturated lowlands	6	Sedge Fen

* Two other till associations in the High Subarctic are:

(1) *Lynx Lake (1 and 2)* – noncalcareous till, sandstone-derived;

(2) *Coldblow Lake (1 and 2)* – noncalcareous till from red sandstone.

The catenary sequences of soils and vegetation on both are similar to the *Wolverine Lake 1 and 2* associations.

survival in the face of winter wind blast. Most Cornicularia drumlins are fissure-patterned on the upper and north-facing slopes, although the polygons appear to be relict features.

Landscapes of nonsorted circles or mud boils on finer materials are particularly common northwest of Artillery Lake and in the Thelon Basin. The vegetated 'rims' of the circles support the same species that dominate in other till areas, notably Betula glandulosa, Empetrum nigrum, Loiseleuria procumbens, Alectoria nitidula, Stereocaulon paschale, Cetraria cucullata, and C. nivalis. The centers of the circles are mostly bare due to frost churning, although the above species occasionally manage to invade sparsely and temporarily.

Ice-contact and Fluvial: Hoarfrost River soils are chiefly Eluviated Dystric and Orthic Dystric Brunisols, developed on well-drained sands and gravels of ice-contact and glaciofluvial origin. In the High Subarctic, associated landforms are eskers and their outwash aprons, the vast outwash plains adjacent to the Clarke and Hanbury rivers, and the dunes southeast of Beaverhill Lake. Many outwash plains, dunes, esker crests, and complexes lacking well-defined slopes are subjected to deflation, and soils on these sites are well-drained Orthic Regosols. Gleyed Dystric Brunisols are typical of imperfectly drained toe slopes.

Most eskers in the High Subarctic are features of considerable local relief. They trend east-west and vegetation communities are markedly different on the north-facing and south-facing slopes. Crests support a third community type, strongly affected by wind erosion.

North slopes of eskers support a nearly complete cover of heaths and lichens, dominated by Empetrum nigrum, Ledum decumbens, Vaccinium vitis-idaea, Alectoria nitidula, Cetraria cucullata, Cladonia mitis, and C. rangiferina. Other common species are Betula glandulosa, Arctostaphylos alpina, Alectoria ochroleuca, Cetraria nivalis, and Cladonia amaurocraea. Bryophytes such as Pohlia nutans, Polytrichum piliferum, and Dicranum fuscescens are present though never abundant.

South-facing esker slopes are drier and warmer than those with a northern aspect, and they often support large individuals of Picea glauca. Bare ground is common and the dominant Vaccinium vitis-idaea, Arctostaphylos alpina, Empetrum nigrum, and

Betula glandulosa form a patchy mosaic. Prominent lichens and moss are Cladonia uncialis, Cladonia mitis, and Polytrichum piliferum.

Outwash aprons and patches adjacent to eskers support open Lichen Woodland, floristically similar to Lichen Woodland of the Low Subarctic Ecoregion. Both Picea glauca and P. mariana may occur, with the latter more common. The ground cover is dominated by lichens (Cetraria nivalis, Cladonia mitis, Stereocaulon paschale, and Cetraria islandica) and Vaccinium vitis-idaea. Other common species are Ledum decumbens, Cladonia cornuta, and C. deformis. Dicranum fuscescens, Ptilidium ciliare, and Cladonia rangiferina occur in more mesic microsites.

Areas of active wind erosion generally lack vegetation, but patchy growth occurs where plants have stabilized the soil. In these situations, Polytrichum piliferum, Vaccinium uliginosum, Arctostaphylos alpina, and Cetraria cucullata dominate, along with scattered individuals or small stands of Picea glauca. Where boulders are present, rock lichens (Actinogyra mühlenbergii, Parmelia stygia, and Rhizocarpon geographicum) dominate the scene.

Wetlands: Sled Lake soils are composed of peat materials containing permafrost, either deep (Fibric Organic Cryosols, Mesic Organic Cryosols) or less than one meter deep (Terric Fibric Organic Cryosols, Terric Mesic Organic Cryosols). The upper 35-45 cm of these peatlands is unfrozen but below this depth there is a medium-to-high ice content in the form of ice crystals, veins, and wedges. Patterned features range from peat plateaus with polygonal surfaces in the Forest Tundra to high-center polygons in the Shrub Tundra. Unpatterned or weakly patterned sedge meadows are a widespread component of the tundra landscape.

Polygonal peat plateaus appear to be composed of Sphagnum fuscum and S. nemoreum; they have a surface cover of Heath-Lichen and Shrub-Heath with sedges prominent in the fissures. The usual species are ubiquitous: Betula glandulosa, Ledum decumbens, Vaccinium vitis-idaea, Rubus chamaemorus, Cladonia rangiferina, and C. mitis. The most southerly sites also include Empetrum nigrum, Vaccinium uliginosum, and Andromeda polifolia. Frequent but never abundant lichens are Cladonia amaurocraea, C. uncialis, C. deformis, Cetraria cucullata, and C. nivalis. Trees do not occur on organic terrain in this ecoregion.

The spatial organization of vegetation on polygonal peat plateaus is strongly influenced by the dimensions of the ice-wedge fissures and the degree by which erosion has reduced cover on the raised portions. In narrow troughs Ledum decumbens is abundant with sedges, while in wide troughs the sedges are dominant.

Sedge Fens are the common lowland tundra communities, consisting of relatively few species: Carex rotundata, C. bigelowii, Scirpus caespitosus, and Eriophorum vaginatum. Accompanying them are the usual dwarf shrubs plus Cladina rangiferina and the mosses Dicranum groenlandicum and Sphagnum nemoreum. All fens, as peatland types, are placed in the Sled Lake association; on the other hand, meadows are peaty phases of Rego Gleysols or Gleysolic Turbic Cryosols of the other soil associations.

A 'hybrid' type of peatland is common in the Forest Tundra ecotone west of Lac du Rocher and Lac Nez Croche, consisting of Sedge Fen interrupted by darker 'strings' of Heath-Lichen similar to that on raised parts of polygonal peat plateaus. These striped bog-and-fen complexes appear to be genetically different from string bogs of the southern Boreal in that they are completely underlain by permafrost at about 50 cm depth.

LOW SUBARCTIC

Landscape patterns of the major terrain types are shown diagrammatically in Figure 4. Some of the variations due to materials and topographic position are discussed next.

Till Landforms: The Porter Lake soil association is noncalcareous sandy loam and loamy sand glacial till derived mainly from granitic rocks. Associated landforms are drumlins, flutings, ribbed moraine, and ground moraine. Till cover is deep or shallow over bedrock.

Open Lichen Woodland is the quintessential vegetation type on well-drained uplands in the Low Subarctic Ecoregion. Picea mariana dominates the arboreal layer while Vaccinium vitis-idaea with Cladina mitis and Cetraria nivalis dominate ground cover with such species of lesser importance as Vaccinium uliginosum, Empetrum nigrum, Ledum groenlandicum, Cladonia deformis, Cladina rangiferina, Stereocaulon paschale, Polytrichum piliferum, Ptilidium ciliare, Pleurozium schreberi, and Dicranum spp. Where till is very stony, or where bedrock outcrops occur, the Rock Lichen community is prominent.

On drumlin crests and north-facing slopes the vegetation is generally as described, but there are minor differences on south-facing slopes. Here Arctostaphylos uva-ursi, Cladina, Cladonia, and both Ledum species are absent. Eluviated Dystric Brunisols prevail regardless of aspect, changing to Gleyed Dystric Brunisols on lower slopes near the till/bog transition. Still lower, with poorer drainage, peaty phase Rego Gleysols appear and grade into Organic Cryosols of the Dymond Lake soil association.

Ice-contact and Fluvial: The Odin Lake soil association is based on landforms of ice-contact or glaciofluvial origin in the Low Subarctic. These soils, composed of noncalcareous sands and gravels, are occasionally eroded in patches on the surface. The landforms contain no permafrost within the soil layer and their surfaces show no frost-patterning.

Outwash areas, which may be flat or sloping, are invariably well-drained with Eluviated Dystric Brunisol profiles. Only two species are ubiquitous: Picea mariana and Vaccinium vitis-idaea. The lichen flora is diverse, dominated by Cladonia amaurocraea, Cladina mitis, C. rangiferina, Stereocaulon paschale, and Cetraria nivalis.

Eskers provide strong local relief; they show marked vegetation differences corresponding with differences in aspect. South-facing slopes are very dry and usually have at least one-third bare ground. As a result, vegetation is patchy and species-poor. Picea glauca and Betula papyrifera comprise the tree layer, Arctostaphylos uva-ursi and Vaccinium vitis-idaea the dwarf shrub layer. Cladina mitis is the only common lichen. Soils on esker slopes are very well-drained Orthic Dystric Brunisols or Eluviated Dystric Brunisols. Esker crests display similar patterns of vegetation and soils.

Esker north slopes are comparatively rich floristically. Picea mariana often occurs in dense stands with Vaccinium vitis-idaea, Cladina rangiferina, and Ptilidium ciliare dominant in the understory. Other common species of the community are Ledum decumbens, L. groenlandicum, Cetraria cucullata, Dicranum polysetum, Hylocomium splendens, and Pleurozium schreberi. The soils are moderately well-drained to well-drained Eluviated Dystric Brunisols.

Where esker flanks grade into lowlands and soils become less well drained, Dystric Brunisols grade into Gleyed Dystric Brunisols or, at the edge of peatlands, into peaty

phase Rego Gleysols supporting peatland mosses and shrubs.

Wetlands: The Dymond Lake soil association consists of organic crysols on deep fibric *Sphagnum* peat or on mesic forest and/or fen peat. Almost all of these soils are associated with permafrost peat plateaus and the relatively rare palsas. Ice content is medium to high in the form of segregated crystals, veins, and lenses.

The vegetation is characteristic of acid peatlands throughout the north. Heaths, lichens, and *Sphagnum* mosses (especially *S. fuscum*) dominate plus a number of sedges in the wet hollows. Common species are *Ledum decumbens*, *L. groenlandicum*, *Vaccinium uliginosum*, *V. vitis-idaea*, *Andromeda polifolia*, *Empetrum nigrum*, and *Rubus chamaemorus*. Between *Sphagnum* mounds, or on dead peat surfaces, *Cetraria nivalis*, *Cladina rangiferina*, and *C. mitis* flourish but *Stereocaulon paschale* is absent. *Betula glandulosa* and *Picea mariana* are present on some peat plateaus but are absent on others. However, the latter species seems to be influenced by a climatic gradient, for it is present on the Dymond Lake soils in the western part of the ecoregion but absent in the eastern part. Thaw pockets in peatlands support a 'poor fen' vegetation of *Carex limosa*, *C. magellanica*, *C. aquatilis*, *Eriophorum brachyantherum*, *Scheuchzeria palustris*, and *S. magellanicum*. Water tracks through peat plateaus, on slopes giving a 'rilled' appearance to the peatlands, are densely covered with *Scirpus caespitosus* and *Eriophorum vaginatum* plus several common carices (*Carex membranacea* and *C. rariflora*).

HIGH AND MID BOREAL

The generalized Boreal landscape patterns are shown in Figure 5. The following descriptions apply mostly to the High Boreal (Precambrian Uplands), which constitutes a major part of the map area. Briefer discussion is devoted to the Mid Boreal.

Till/Bedrock and Till: Much of the High Boreal Ecoregion is exposed bedrock or bedrock-controlled shallow drift. On such sites the soils, where present, belong to the Nonacho Lake 2 soil association, characterized by a veneer (less than 1 m deep) of sandy loam to loamy sand glacial till derived mainly from granitic rocks. Common soil types are lithic phases of Eluviated Dystric Brunisols, with peaty phase Rego Gleysols in well-vegetated bedrock fractures. Exposed bedrock is covered by Rock Lichen and Rock Lichen Woodland

communities. Dominant species are the trees *Picea mariana* and *Pinus banksiana*, and the rock (saxicolous) lichens *Actinogyra muhlenbergii*, *Rhizocarpon geographicum*, *Parmelia centrifuga*, *P. hyperoptica*, and *Peltigera polydactyla*. Fruticose lichens, particularly *Cladina mitis* and *C. rangiferina*, are also present. Along bedrock fractures, where soil is deeper, there is increased diversity of shrubs, lichens, and mosses.

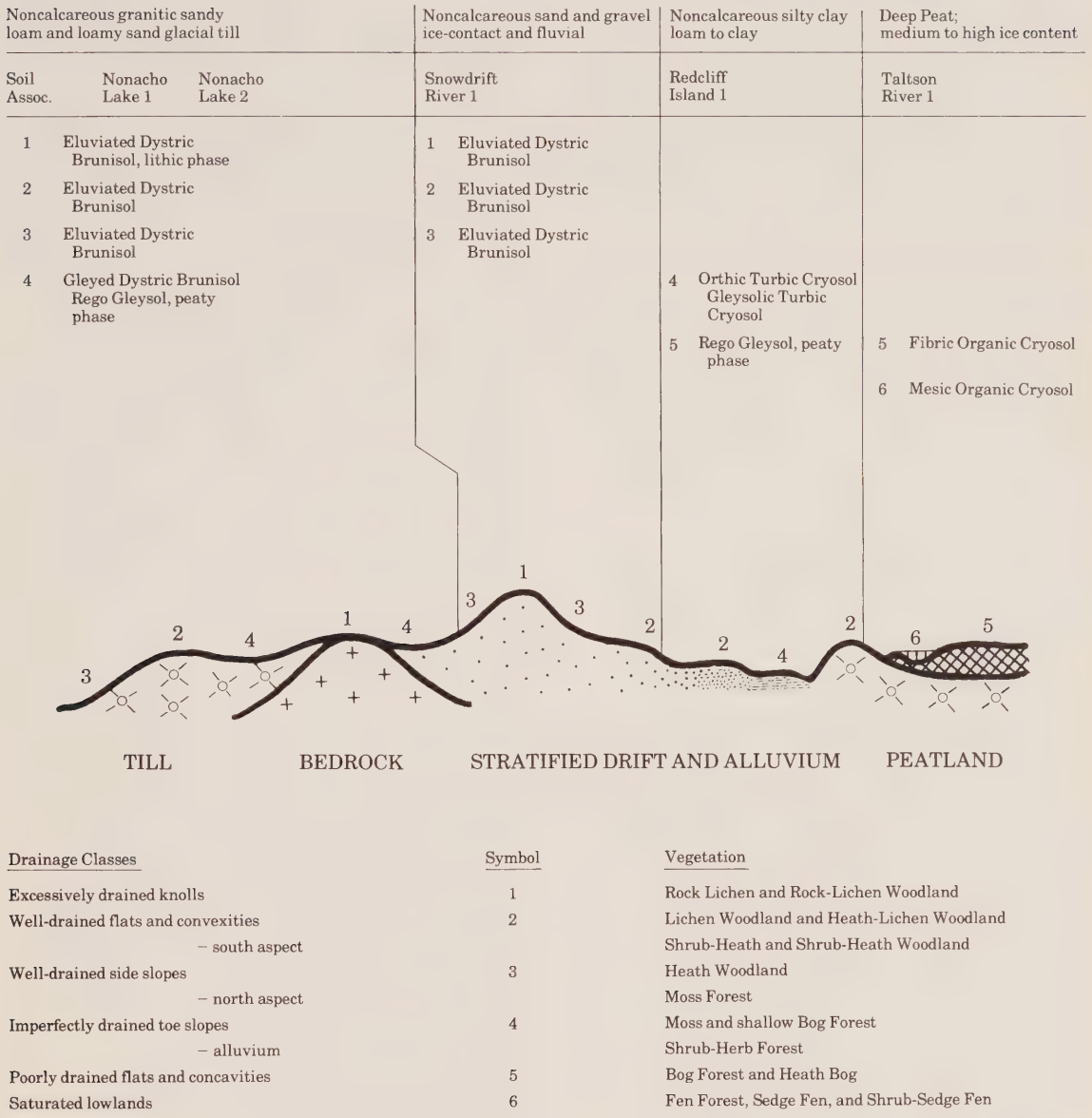
Very shallow till over bedrock generally supports droughty Lichen Woodland or Shrub-Heath Woodland. However, where the till veneer is deep enough to provide adequate rooting, yet with the bedrock close enough to the surface to maintain a moisture supply, a moss-floored, closed-crown forest is typical. Boreal mosses such as *Hylocomium splendens* and *Pleurozium schreberi* are common, along with *Vaccinium vitis-idaea*, *Ledum groenlandicum*, *Cladina mitis*, *C. rangiferina*, and *C. stellaris*.

Less prevalent than the shallow tills are the deeper deposits, noncalcareous and derived mainly from granitic rocks, classified as the Nonacho Lake 1 soil association. The vegetation is similar to that of bedrock-controlled shallow drift. Eluviated Dystric Brunisols characterize well-drained sites, grading into perfectly drained Gleyed Dystric Brunisols and poorly drained peaty phase Rego Gleysols.

Ice-Contact and Fluvial: Soils of the Snowdrift River 1 soil association are noncalcareous sands and gravels of ice-contact, glaciofluvial or recent fluvial origin. In the High Boreal Ecoregion, these soils are associated with eskers, outwash plains, and terraces of the major rivers. Soils of the well-drained, vegetated sites are Eluviated or Orthic Dystric Brunisols, with Orthic Regosols on deflated sites. Gleyed Dystric Brunisols or peaty phase Rego Gleysols can occur on esker toe slopes or adjacent depressions; they are transitional to organic soils of the Taltson River Association.

Eskers are comparatively restricted in the Boreal compared to the Low and High Subarctic ecoregions. Where they do occur, their south-facing slopes are species-poor, and unvegetated ground accounts for roughly one-third of the surface. Dominant trees are *Picea mariana* and *Betula papyrifera*, with the shrubs *Arctostaphylos uva-ursi*, *Vaccinium vitis-idaea*, and *Juniperus communis*. Lichens, mosses, and herbs are not abundant and *Calamagrostis purpurascens* is the only

Figure 5: High and Mid Boreal: Landform-Soil-Vegetation Catenas



* Additional soils of the Slave River Lowland on weakly calcareous sandy lacustrine-deltaic and alluvium, respectively, are *Fort Smith 1* Orthic, Eluviated, and Gleyed Eutric Brunisols, and *Norberta* Orthic and Cumulic Regosols. Both have Rego Gleysols, peaty phase.

significant graminoid. On north-facing slopes, the vegetation is more diverse with an important non-vascular component: Cladina mitis, C. rangiferina, Cladonia amaurocraea, C. gracilis, and Cetraria nivalis are dominant lichens, while Ptilidium ciliare and Polytrichum piliferum are the most abundant bryophytes. Vaccinium vitis-idaea is the most common dwarf shrub, though Empetrum nigrum, Ledum decumbens, and L. groenlandicum are locally important. Picea mariana is the dominant tree though Pinus banksiana and Picea glauca frequently 'spill over' from the south and top sides.

The broad, well-developed valley of the Snowdrift River (from which the ice-contact and fluvial soil association is named) crosses both Boreal and Subarctic ecoregions south of the East Arm. It typifies several other broad, sandy river valleys (e.g., the Taltson and the Thoa) and therefore merits particular attention. Sandy terraces above the river display an open Lichen Woodland vegetation found throughout the High Boreal Ecoregion and similar to that on upland surfaces in the Low Subarctic Ecoregion. Picea mariana and Pinus banksiana are the common trees, and the understory is dominated by a thick mat of Cladina mitis, Cladonia gracilis, C. amaurocraea, Stereocaulon paschale, and Cetraria nivalis.

Also important are Vaccinium vitis-idaea and the mosses Polytrichum juniperinum and P. piliferum. Along recently abandoned point bar deposits, silty sands support Shrub Thicket vegetation with prominent Salix planifolia. Old meander scars form a swell-and-swale topography with subtle vegetation differences. The rises are usually less than one meter above the hollows, and it is often difficult to determine patterns on the ground. From the air, the major difference can be seen as due to lichen cover, with yellowish Cladina and Cetraria species dominating rises (with Ledum groenlandicum) and the whitish Stereocaulon paschale and Cladonia rangiferina dominating hollows. In both situations, important species include Picea mariana, Betula glandulosa, Vaccinium uliginosum, V. vitis-idaea, Polytrichum juniperinum, and Cladina mitis. Some of the rises display a prominent network of hummocks, and the inclusion of organic material beneath the hummocks indicates a periglacial origin. All soils adjacent to the Snowdrift River are Cumulic Regosols.

Lacustrine and Alluvial: In the basin of the East Arm of Great Slave Lake, glacial lake deposits have produced a noncalcareous clay-rich series of soils that texturally are

silty clay loams to clays. These soils belong to the Redcliff Island 1 soil association; they are characterized by a medium-to-high ice content (as segregated crystals, veins, and lenses) and by surficial earth hummocks. Orthic Turbic Cryosols are common on well-drained and imperfectly drained sites, while poorly drained soils are Gleysolic Turbic Cryosols. The vegetation within the East Arm basin is structurally similar to other areas of the Boreal forest but, because the flora is enriched with more southern species and the climate is ameliorated by the lake, the area is placed in the Mid Boreal Ecoregion.

The Slave Lowlands cut across the extreme southwest corner of the LRMA and here, as the land surface drops westward below the 200 m contour, lacustrine-deltaic and alluvial soils predominate. We have placed the lowlands in the Mid Boreal Ecoregion because of the prominence of broadleaf forests and associated 'southern' species. However, there is a transitional zone with the Precambrian Uplands (High Boreal) to the east where bedrock ridges rise above the lacustrine plain. Here the upland tills support soils that are logically placed in the Nonacho soil association, as shown in the soils map.

In the Slave River Lowlands, two soil associations are recognized: the more extensive Fort Smith 1 on weakly calcareous sandy to loamy lacustrine or deltaic materials, and the less common Norberta 1 on weakly calcareous sandy to loamy sand alluvium. Neither exhibits evidence of ground ice within nor patterned ground at the surface. Well-drained profiles are Orthic Eutric and Eluviated Eutric Brunisols or Orthic and Cumulic Regosols that support forests of mixed or pure Populus tremuloides, Pinus banksiana, Picea glauca, and Populus balsamifera. Such forests are relatively 'rich' with Shrub-Herb undergrowth in which such species as Salix bebbiana, Alnus incana, Rosa acicularis, Aralia nudicaulis, and Cornus canadensis are prominent. The low relief surface is not conducive to good drainage and there are extensive areas of Gleyed Eutric Brunisols and Rego Gleysols whose peaty phases support vast sedge and sedge meadows with abundant species such as Carex atherodes, C. rostrata, Salix bebbiana, and S. serissima.

Wetlands: The Taltson River 1 soil association comprises deep fibric Sphagnum peat and mesic forest and/or fen peat. All such soils, with the exception of wet fens through which water moves seasonally, are

imperfectly-to-poorly drained Fibric and Mesic Cryosols in the form of aggrading peat, palsas, and peat plateaus.

The vegetation of peat plateaus and palsas in the High Boreal is similar to that of the Low Subarctic, i.e., Heath-Lichen Bog and Lichen Bog Woodland characterized by Sphagnum fuscum, Ledum decumbens, L. groenlandicum, Vaccinium vitis-idaea, Rubus chamaemorus, Cetraria nivalis, Cladina mitis, and C.

rangiferina. Pools in the peat and water tracks are less acidic than peat plateaus and palsas, and the vegetation is Sedge Fen or Sedge-Shrub Fen. Several species of Carex and Equisetum dominate the wetter areas, while the better drained sites support a richer vegetation of Ledum groenlandicum, Vaccinium vitis-idaea, Arctostaphylos rubra, Cladina mitis, and such forest mosses as Tomenthypnum nitens, Aulacomnium palustre, and Hylocomium splendens.

SECTION H

BEDROCK GEOLOGY AND PHYSIOGRAPHY

BEDROCK GEOLOGY AND PHYSIOGRAPHY

Two structural parts of the Canadian Shield underlie the LRMA: the Slave Province in the northwest quarter (bounded south and east by Great Slave Lake and the Artillery to Clinton-Colden Lake Axis) and the Churchill Province that extends beneath and beyond the other three quarters. Both are similar lithologically although they represent different tectonic developments, in the Archean and Proterozoic eons respectively. They contribute to the widespread repetitiveness of surficial materials with similar topographies in the LRMA.

Most abundant and comprising about 45% of the whole area are gneissic and impure granitic rocks that often contain patches of other forms such as sedimentary and volcanic schists, diorite, and gabbro. Massive granites with few gneissic inclusions also occur, but their surface expression is only about 15%. A somewhat larger area of gneiss, schist, gabbro, diorite, and migmatite derived from sedimentary and volcanic rocks is scattered through the granitic matrix of Wholodaia and Selwyn lakes. Also in the southeast quarter there is a relatively small exposure of granulite and charnockite west of Firedrake Lake.

Several important lithologic discontinuities are expressed in the remaining 20% of the surface. A belt of mixed metamorphic and sedimentary rocks (impure quartzite and greywacke, with minor slate, phyllite, and schist) lies south of the East Arm, trending sinuously from Nonacho Lake to Hill Island Lake, roughly parallel to 110° longitude. It is marked by a visual structural change in terrain. Non-marine sandstones and shales occur in the extreme northeast and southeast, in the latter as Quaternary deposits near Fort Smith. Although bedrock crops out uncommonly on the Thelon Plain, it is assumed (Wright, 1967) that Dubawnt sandstone lies beneath the surface sediments. The reddish colour of the surficial materials in the northeast corner probably reflects this source.

The physiographic divisions recognized by Bostock (1970), based on relief and geology, are shown in Figure 6. Note the coincidence with some of the ecological boundaries in the ecological map.

1. SLAVE LOWLANDS

The extreme southwestern corner of the LRMA is part of the Great Slave Plain. This physiographic unit is based on a surface of

Paleozoic strata with some later sequences of sandstone, shale, and coal. It is mantled by postglacial alluvial sediments that are occasionally interrupted by low scarps of resistant carbonaceous rock. Elevations within the Slave Lowlands are generally below 200 m and nowhere exceed 250 m.

2. EAST ARM HILLS

This physiographic unit encompasses the eastern extension of Great Slave Lake. It comprises Precambrian down-faulted, folded, and differentially eroded sediments and gabbro sills, within and surrounding the lake basin. The slope of the land is to the south, terminating at the imposing McDonald Fault scarp.

3. THELON PLAIN

This physiographic unit closely corresponds with the Dubawnt group of flat-lying sedimentary and associated igneous rocks (Wright, 1967), expressed in the LRMA by Dubawnt sandstones. The superimposed Thelon Basin occupies a regional low of approximately 200 m ASL which supported a large proglacial lake, drained between 8000 and 7000 BP. Bedrock is therefore largely mantled with recent sediments.

4. KAZAN UPLAND

The most extensive unit in the LRMA, this typical Shield upland lies to the south of the McDonald Fault and its extension to the Hanbury-Thelon rivers confluence, bounded west and east by the Slave Lowlands and the Thelon Plain respectively. It reaches a height of 590 m ASL in the central south Abitau-Dunvegan lakes area, falling off gently to 200 m ASL at the aforementioned boundaries. Local relief is rarely more than 30-60 m.

A line from the Tazin River at the south to Nonacho Lake on the Taltson River, approximately parallel to the north-south 350 m contour, delineates the eastern side of a sedimentary and metamorphic belt. It is a visible boundary on LANDSAT imagery, marking an obvious change in terrain.

5. BACK LOWLAND

In the LRMA, the Back Lowland is a wedge with its apex at the southern tip of Artillery Lake, its southern boundary along the extension of the McDonald Fault, and its western boundary along Artillery and Clinton-Colden lakes. Except for the Lockhart River system, drainage is northeast by the Back River, over

a surface that is generally below 400 m in altitude.

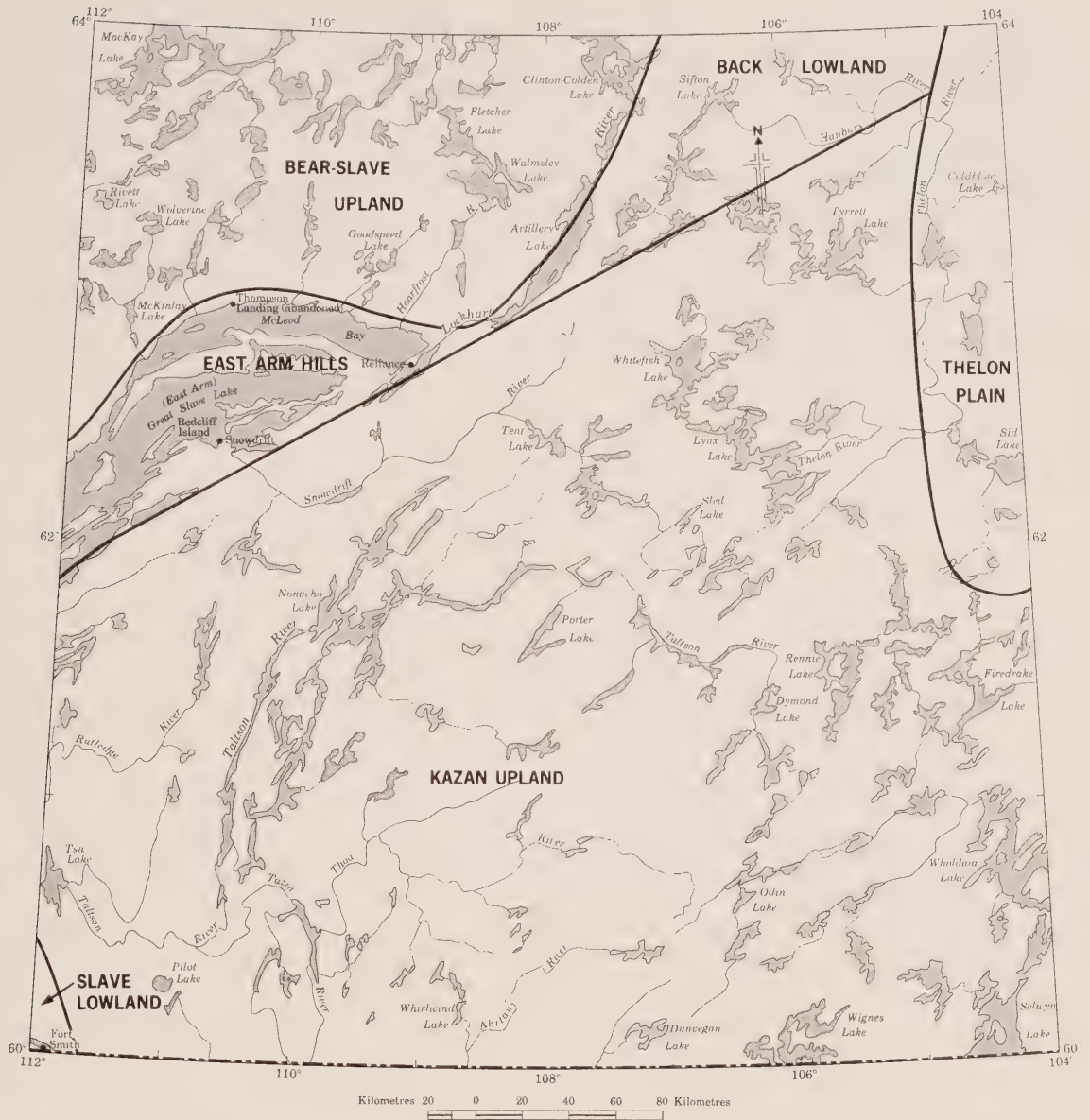
6. BEAR-SLAVE UPLAND

Though part of the structural Slave Province, this physiographic unit is not unlike the Churchill Province south of the McDonald Fault. Its surface expression is primarily a low-relief peneplain at 300-400 m altitude,

marked by numerous lakes.

The physiographic divisions have been used to some extent in delineating ecodistricts on the ecological map, as explained earlier in this report. However, the Back Lowland is not recognized as significantly different in surface features from the Kazan Upland, and the latter has been subdivided into nine units on the basis of relief, lake forms, and vegetation.

Figure 6: Physiographic divisions of the LRMA (after Bostock, 1970)



SECTION I

DRAINAGE

DRAINAGE

The LRMA is drained through seven major basins (Figure 7, Table 3), each comprising many tributary streams and numerous small lakes. Except for a few large rivers and main tributaries, the drainage pattern is

largely disorganized. The eastern third of the area drains north and east to Hudson Bay, while the waters of the remaining two-thirds empty into the Arctic Ocean via the Mackenzie River. Note that water covers one-quarter to one-third of the surface, ranging in the sub-basins from a low of 18% to a high of 39%.

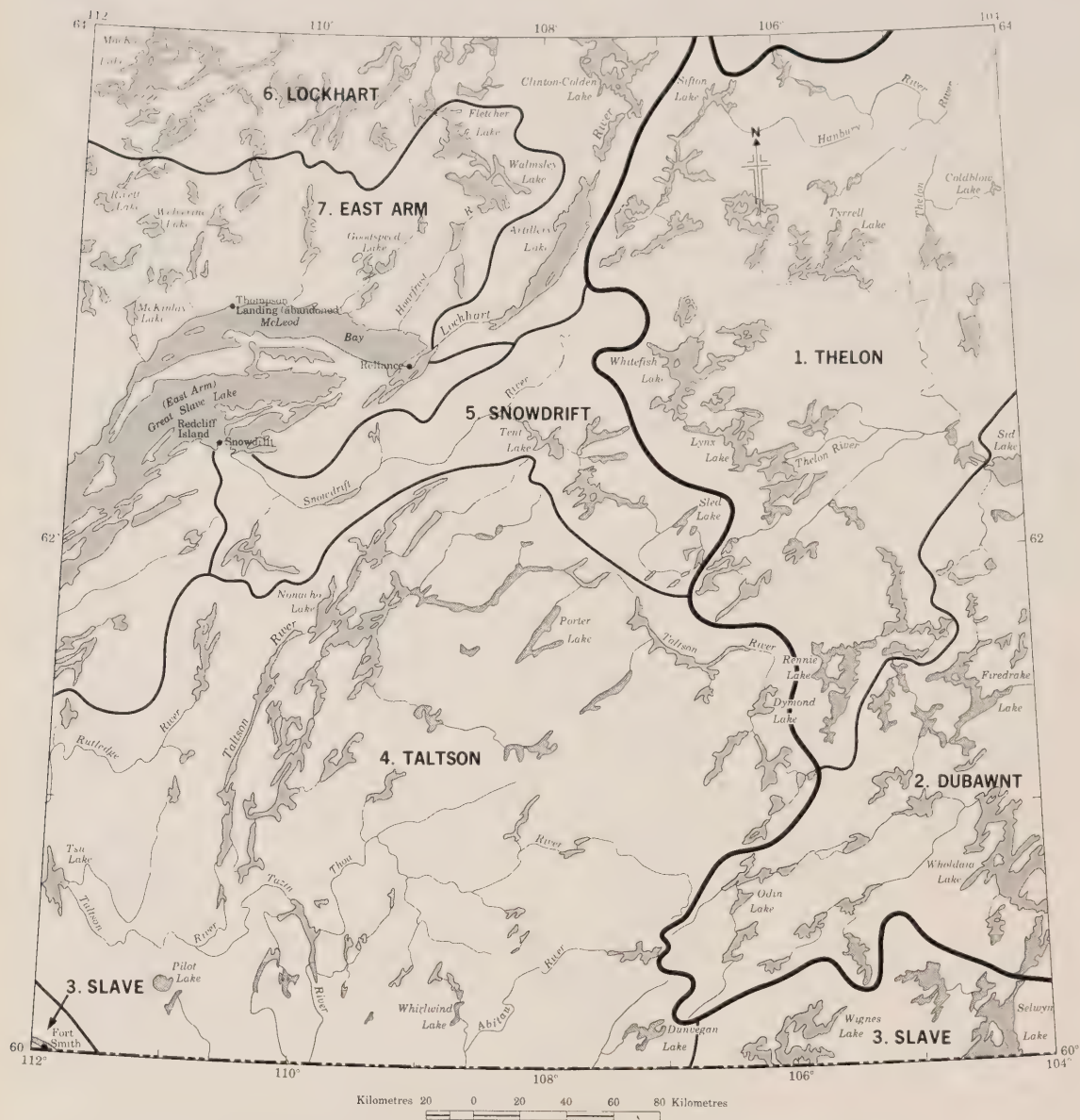
Table 3: Drainage basins and some of their characteristics in the LRMA

Basin Number and Name	Area in km ² (% of LRMA)	Sub-basins*	Percent** Surface Water	Slope** in ft. /mile	Drainage** Density
1. Thelon	44,000 (22)	6JA (south) 6JB (north)	33 18	2.5 2	0.0167 0.0278
2. Dubawnt	26,000 (13)	6KA	28	1.4	0.0426
3. Slave	8,000 (4)	7LE 7LC 7NB	no data no data no data		
4. Taltson	56,000 (28)	7QC (south) 7QD (north)	18 39	2 2	0.1013 0.0341
5. Snowdrift	12,000 (6)	7QB	24	6	0.0253
6. Lockhart	26,000 (13)	7RA 7RB 7RC 7RD	36 33 35 35	1 2 2 3	0.0178 0.0465 0.0199 no data
7. East Arm	26,000 (13)	7QA (south) 7SC (north)	35 25	9 7	0.0062 0.0108

* Sub-basins recognized by the Water Resources Branch, Inland Waters Directorate, Environment Canada.

** The data on percent surface water, slope in feet per mile, and drainage density (miles of stream per square mile of basin) are taken from the map by A. Soucy in Lafond *et al.*, 1971.

Figure 7: Major drainage basins of the LRMA. The thicker line boundary represents a major drainage divide -- basins 1 and 2 drain toward Hudson Bay, the rest toward the Beaufort Sea.



1. THELON

The Thelon River basin is one of the major systems draining into Hudson Bay. Its headwaters comprise 22% of the LRMA. Important tributaries of the Thelon are the Darrell, Hanbury, Mary Frances, and Elk rivers. The western and southern portions of this basin lie beyond the Thelon Plain physiographic region and the Dubawnt Sandstone geologic province, and are characterized by a maze of small lakes. Among the larger lakes in the Thelon basin are Tyrrell, Whitefish, Lynx, and Rennie.

2. DUBAWNT

Approximately 13% of the LRMA drains northeast through the Dubawnt River and joins the Thelon west of Aberdeen Lake. The headwaters of the Dubawnt River are at Carleton Lake on the Abitau-Dunvegan height-of-land; there are no substantial tributaries within the area. Wholdaia and Firedrake are the largest lakes.

3. SLAVE

There are two separated areas of drainage of the Slave River basin in the LRMA. One is in the southeast corner where Selwyn, Ingalls, Wignes, and Scott lakes drain southward to Black Lake in Saskatchewan, then via Lake Athabasca to the Slave River and Great Slave Lake. The other comprises the Slave Lowlands in the southwest corner, where small streams and scattered lakes connect directly with the Slave River. These two areas occupy 4% of the LRMA.

4. TALTSOON

The Taltson River basin is the largest of the drainage systems in the map area, covering 28% of the landscape. Headwaters of the system are in the vicinity of Sylvan Lake, and eventual entry into the Mackenzie system is via the south shore of Great Slave Lake, some 60 km east of the mouth of the Slave River. Major tributaries and sub-basins of the Taltson are Tazin, Thoa, Tethul, Abitau, and Rutledge rivers. The largest lakes -- Hill Island, Thekulthili, Nonacho, and Rutledge -- are in the western part of the basin; the only concentration of small lakes is in the southeast near Abitau and Dunvegan lakes. Damming of the Taltson 55 km northeast of Fort Smith has flooded most of the lakes along the route of the river as far north as Nonacho and Gray lakes.

5. SNOWDRIFT

The Snowdrift River basin comprises approximately 6% of the map area, draining into the East Arm of Great Slave Lake. The only major tributary is the Eileen River, and Eileen and Gagnon are the largest lakes.

6. LOCKHART

About 13% of the LRMA is drained through the Lockhart River basin in the northeast corner of Great Slave Lake. The headwaters of the Lockhart are west of MacKay Lake, with subsequent drainage east to Clinton-Colden Lake and south through Artillery Lake to the East Arm. This system is characterized by many large lakes, including MacKay, Aylmer, Clinton-Colden, and Artillery. However, there are no major tributaries.

7. EAST ARM

Small streams and rivers drain 13% of the LRMA into the south and north sides of the East Arm. Southwest of Snowdrift River (south side), the Thubun and La Loche rivers comprise 2% of the system. Another 1% is drained through a series of small lakes and creeks between Artillery Lake and the mouth of the Snowdrift. The remainder, between the Lockhart River basin and the north shore, is the major area that drains southward into the lake. The only important river is the Hoarfrost, fed by Fletcher and Walmsley lakes. Minor rivers are McKinlay, Mountain, Waldron, and Barnston.

8. DISCUSSION

If the map of drainage basins (Figure 7) is compared with the ecological map, few coincidences of boundaries will be found. The reason is that the ecological boundaries, located where there are observed changes in the relationships between landforms, vegetation, soils, and (by inference) climate, seldom fall on the heights of land that separate different watersheds. This is true in most low-relief terrain such as that which characterizes the LRMA, for except in the vicinity of the East Arm the slope of the land does not usually exceed two feet per mile. Basin boundaries are far from prominent features; they can only be detected by close study of stream articulations and therefore have limited relevance to environmental stratification.

This should not be interpreted to mean that basins and their delineation are unimportant. Watersheds are functional landscape units whose recognition is necessary when management of the land focusses on water problems. Then the correct stratification

will identify basins and relate them to the ecoregions, ecodistricts, and ecosections.

Although basin boundaries and regional boundaries do not match up, there are some interesting parallelisms. The Slave River drainage in the southwest corner is bounded by a line close to the division between High Boreal conifer forest and Mid Boreal mixed-wood forest. The discrepancy is due to the more fertile soils of the latter ecoregion that extend into the Taltson basin. Another

parallelism exists along the boundary between the eastern drainage to Hudson Bay and the western drainage to the Arctic Ocean: from Artillery Lake to Rennie Lake it is close to the Forest Tundra subregion. The similar relationship on an east-west line between the Lockhart basin-East Arm basin height of land and Forest Tundra suggests that, in some places, the basin boundaries do exert an ecological influence. Possibly there has been a historical effect on rate of species migration during times of climatic change.

SECTION J

SURFICIAL GEOLOGY

SURFICIAL GEOLOGY

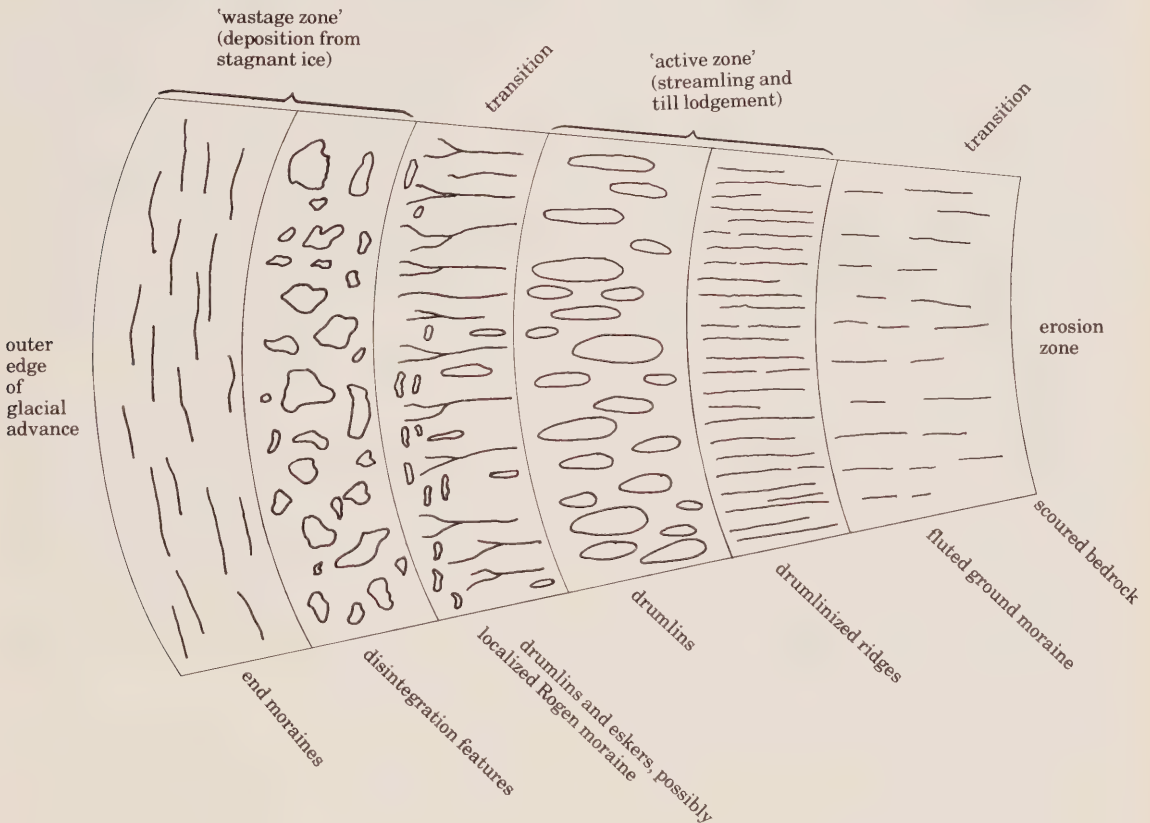
The LRMA lies within the Canadian Shield, dominated by Precambrian bedrock except in the southwest corner. The overall low-relief appearance of the landscape is controlled by features of glacial and postglacial erosion and deposition.

Glaciation was from the east and northeast, producing the sequence of regional landscapes to be expected from a mid-latitude ice sheet. Figure 8 shows the suite of landforms predicted by Sugden and John (1976); the distribution of LRMA glacial landforms seems to correspond with the first 'transition zone' and the 'active zone', i.e., drumlins,

eskers, and ribbed (Rogen) moraine characterize the central, south, and east areas, while drumlinized ridges and fluted ground moraine are common to the northeast. The axis of the streamlined till features is east-west in the north, northeast-southwest in the south, indicating ice retreat directions to the ice divide in northern Keewatin (Lee *et al.*, 1957).

Bedrock control of landform is pronounced on the west side of the LRMA, beginning at about 109° longitude where a belt of sedimentary and volcanic rock ridges shows a pronounced north-south alignment. Here the evidence of glaciation includes striations, thin drift, perched boulders, and erratics on bedrock.

Figure 8: Depositional landscapes expected at periphery of a mid-latitude Pleistocene ice sheet at, or just after, phase of maximum glaciation (after Sugden and John, 1976)



After Sugden and John, 1976.

1. TILL

Depth of surface till varies markedly throughout the LRMA (Figure 9), with thin deposits in some parts of the northeast quarter (for example, east of Clinton-Colden Lake) as well as on the west side. The thickest till appears to be at the highest altitudes (about 500 m) in the south-central (Abitau-Dunvegan) area. Texture is much less variable, though very bouldery till is prominent along the southeast border and throughout the northeast quarter.

Although most till deposits are heterogeneous stony sandy loam and loamy sand, stratified drift is found in many drumlins and drumlinized ridges, indicating the importance of basal meltwater during drumlin formation (Muller, 1974). Also, some drumlins are kettled, suggesting the remodeling of ice-contact stratified drift.

Drumlinization is evident where the drift deepens east of about 110° longitude, not only in the 'classic' Abitau-Dunvegan field but also northward. However, to the northeast, drumlinized ridges and moraine flutings are the more usual expression (as indicated in Figure 10), similar to the terrain that stretches away to Baker Lake in Keewatin.

Ribbed moraine is of limited occurrence in the LRMA; it is best expressed along the east-central border where the western edge of a vast ribbed moraine landscape occurs. The 'ribs' developed transverse to the flow of ice and the landform has been interpreted as indicating areas of glacial readvance. This interpretation is of particular interest, as there is little other evidence of ice-terminal positions in the LRMA.

The extensive Cockburn moraine system, associated with the Cockrane readvance (8400-8000 BP), is recorded in many parts of Canada (for example, at Fort Chipewyan to the south and at MacAlpine Lake to the north), but it has not been detected in the LRMA. It is possible that the west-east change from bedrock-controlled shallow till to deeper till at 109° longitude may correspond to a readvance position associated with the Cockrane episode, for the transition line is roughly equivalent to the ice-terminal position at 8000 BP (Bryson *et al.*, 1969).

2. ICE-CONTACT STRATIFIED DRIFT

Eskers are common features throughout the LRMA, ranging from comparatively small, single-ridged embankment types in the

southwest quarter to the large, multi-ridged systems in the eastern half. Most eskers are flanked by aprons of outwash, and many are interrupted along their length by scour channels of washed bedrock, indicating periods of active subglacial streams carrying little or no sediment.

Glaciofluvial deposits dominate the northeastern quarter, and this area may properly be termed a glaciofluvial landscape. Prominent low eskers with extensive outwash aprons wind east-west for long distances, although north of the Hanbury River the trend of eskers is north-south. These latter eskers terminate in vast outwash plains along the Hanbury and Clarke rivers. Kames are less common features, although a prominent kame complex occurs above the highest beach ridge of Glacial Lake Thelon, east of Beaverhill Lake. Parts of the outwash areas along the Clarke River may be kame terraces. Finally, pitted outwash occurs near Sid Lake, and is part of a large pitted outwash landscape that extends eastward toward Dubawnt Lake.

3. GLACIOLACUSTRINE AND LACUSTRINE SEDIMENTS

Three major glacial lakes, the Thelon, Lockhart, and Hyper-Dubawnt, formed when glacial ice blocked drainages to the north and northeast (Craig, 1964). The lakes are well marked by beach ridges, but varved sediments were not encountered during field work. It appears that glaciolacustrine sedimentation and alteration of already existing features by the lakes was minimal, as ribbed moraine and crescent-shaped drumlins occur within the basins.

LANDSAT imagery, air photo mosaics, and field studies indicate that other areas of the LRMA also experienced proglacial flooding. The Snowdrift River basin, eastern Taltson River and McArthur Lake, and Rennie Lake all show some indications of inundation. Furthermore, it is likely that the fine silts and clays in the East Arm basin of Great Slave Lake resulted from lacustrine sedimentation when lake levels stood higher, as indicated by beach terraces above old Fort Reliance.

4. EOLIAN FEATURES

Postglacial wind effects are weakly expressed in the High Boreal Ecoregion where scattered parabolic 'hairpin' dunes occasionally occur. In the Low Subarctic, wind erosion affects many outwash areas; open sand patches are common, dotted with circular clones of the stabilizing *Empetrum nigrum*. In the High Subarctic, where vegetation is low and the

Figure 9: Generalized zones of till thickness and texture in the LRMA

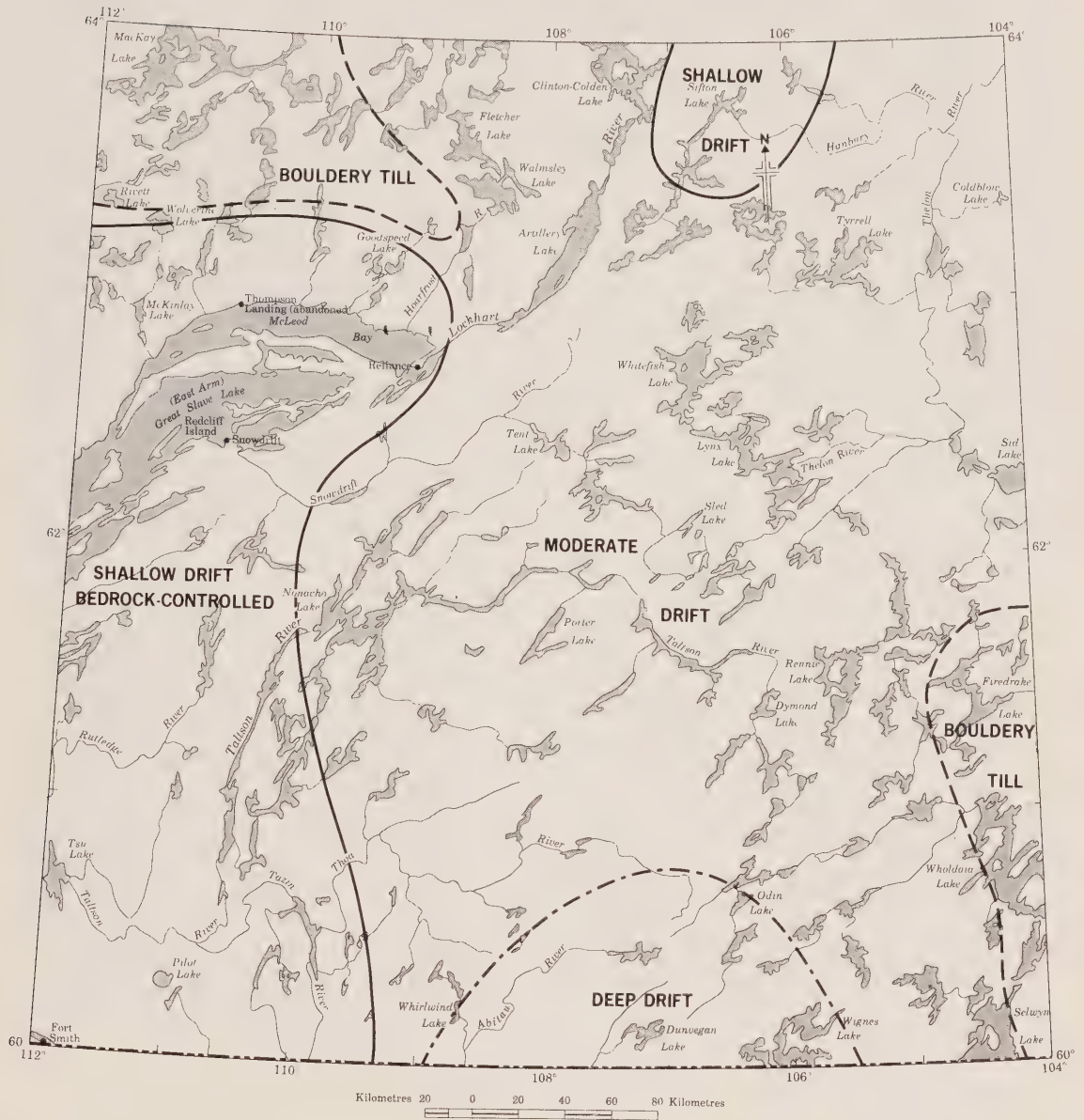
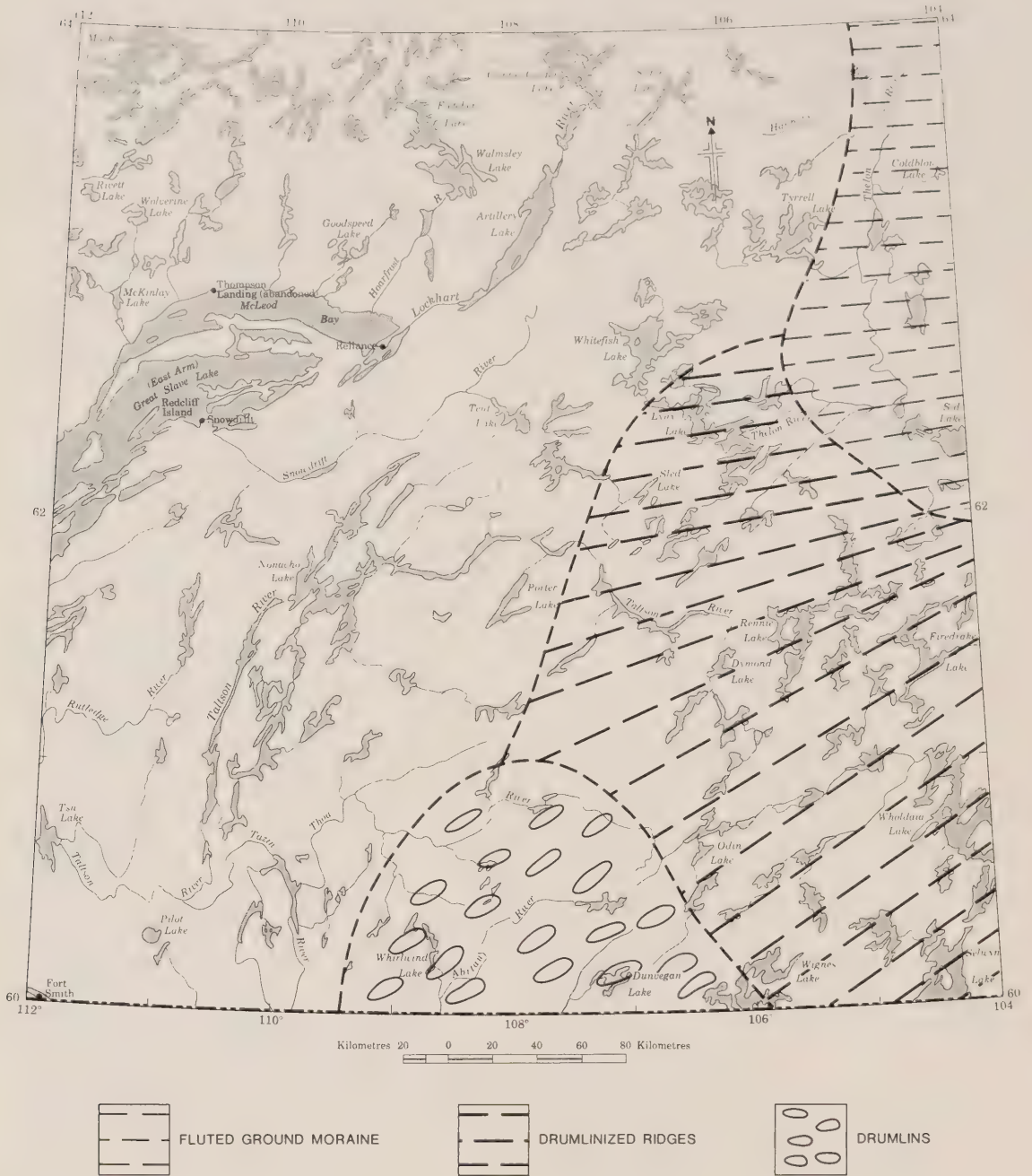


Figure 10: Generalized zones of streamlined morainal landforms in the LRMA



force of the wind is unchecked, eolian processes are of major importance. The numerous broad eskers and outwash plains in the northeast quarter are being eroded today, as evidenced by expanses of bare sand blowouts and leese side sand plumes.

5. PERIGLACIAL FEATURES

Several features of periglacial origin occur in the LRMA, particularly in the High Subarctic Ecoregion. Solifluction on slopes is very limited and is largely restricted to the northwest and north-central areas. Mud boils are more common, but their occurrence is restricted to two areas: between Artillery and Walmsley lakes, and northeast of the confluence of the Clarke, Hanbury, and Thelon rivers. They indicate deposits of poorly sorted sediment with low liquid limits and significant amounts of silt and clay (Shilts, 1974). Boulder fields are conspicuous in the Low and High Subarctic ecoregions, distinguished from bouldery till by the absence of a fine matrix. They may be of periglacial origin, but washing by water has doubtless been an ancillary process in their formation (Dionne, 1978).

Frost cracks form a polygonal pattern on most till uplands north of 63° latitude. These features may be relict. No polygonal surfaces examined in the course of field work gave any indication of recent ice wedge activity. While permafrost occurs at approximately 40 cm in most peatlands in the LRMA, it appears to plunge deeply at the peat/material interface, and at present it does not seem to be an important factor shaping upland sites. For example, excavation to 2.2 m in terrain associated with nonsorted circles near Lynx Lake failed to locate frozen ground in August 1977.

6. DISCUSSION

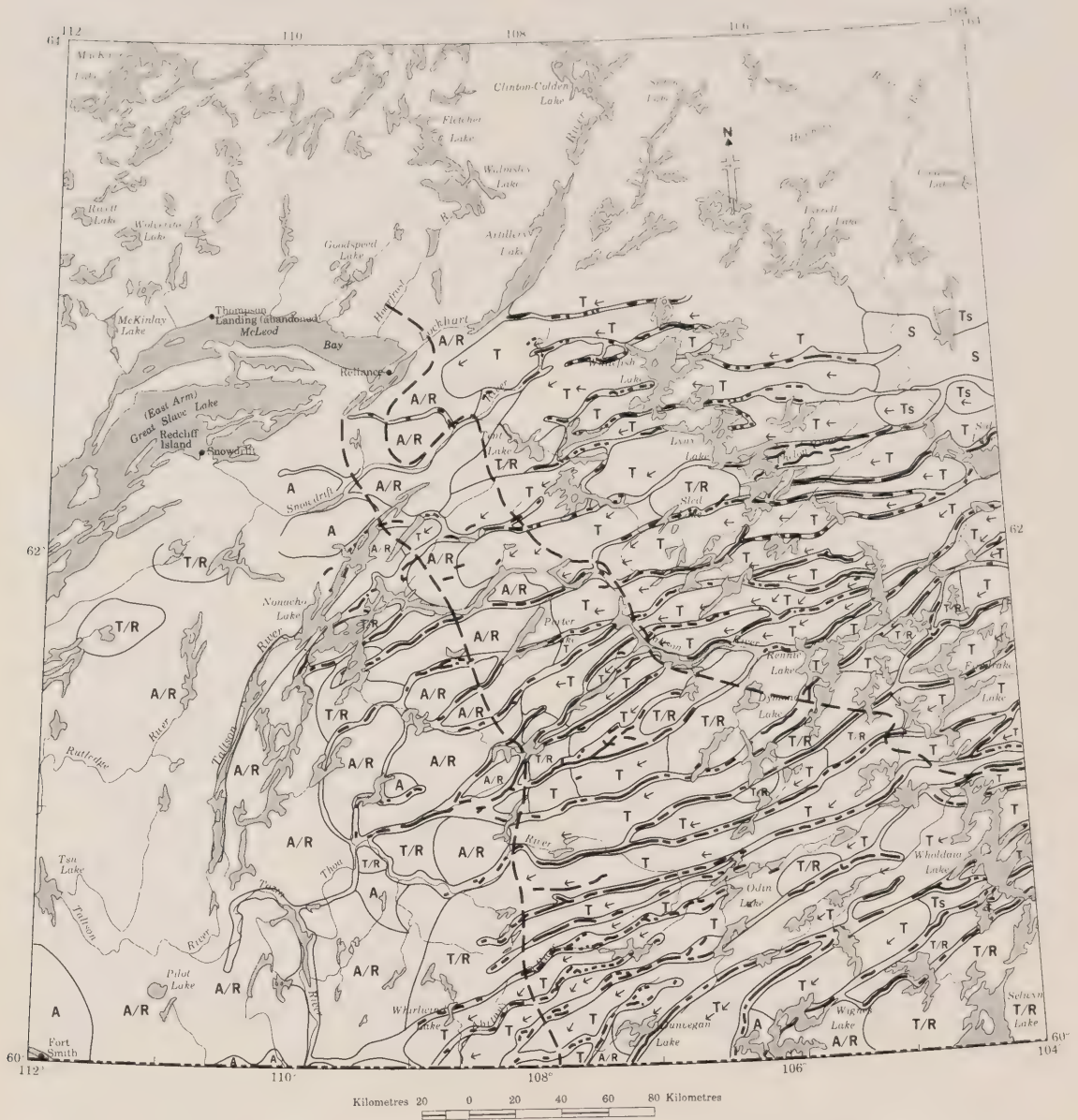
The landforms that express surficial geology are very important to ecological land classification because they have both morphogenetic and functional significance. At the third (ecosection) level of landscape division,

below ecoregions and ecodistricts, they are used to delineate the vegetation-soil patterns variously called 'catenas', 'associations', or 'land systems'. Examples in terrain such as the LRMA are drumlin fields, alluvial plains, bedrock-controlled shallow till areas, extensive peatlands, esker trains, and their associated outwash and scoured bedrock.

The importance of landforms is their control over landscape ecosystem development and productivity. The manner in which the earth's surface receives and processes energy and materials (radiation, precipitation) is mediated by the surficial materials and their shapes. Thus, a dune field provides an intrinsically different environment from a ribbed moraine or a floodplain, though all three may coexist side by side under the same macroclimatic regime (i.e., within the same ecoregion).

We have not made a detailed subdivision of the ecoregions and ecodistricts into surficial units as a basis for delineating third-order landscape ecosystem units. General descriptions of the main patterns within ecoregions, illustrated diagrammatically with catenary profiles, have been presented in the first part of the report. Here we show a preliminary map (Figure 11), prepared from 1:60,000 mosaics, outlining areas of streamlined till, bedrock-controlled till, esker trains, and various other drift landforms of the LRMA south of 63° latitude. The Low Subarctic Ecoregion is heavily outlined. Its western boundary (between High Boreal and Low Subarctic), which was originally drawn at the change from forest to woodland, approximates the transition from shallow bedrock-controlled drift on the west (symbol A/R) to deep drift on the east (symbol T). The right boundary (between Low Subarctic and High Subarctic) is also based on a structural change in the vegetation (disappearance of trees from the rises), but it does not correlate with any perceivable surficial change.

Figure 11: Generalized surficial geology of the LRMA south of 63° latitude.
Low Subarctic Ecoregion is between dotted lines.



T MOULDED TILL: STREAMLINE FORMS,
UNCONTROLLED MATERIALS

A DRIFT WITHOUT PRONOUNCED
BEDROCK CONTROL

Ts SANDY MOULDED TILL

A/R THIN DRIFT WITH
BEDROCK (R) CONTROL

T/R MOULDED TILL WITH
BEDROCK (R) CONTROL

S SAND PLAIN

 GLACIO-FLUVIAL OUTWASH
(ESKER TRAINS)

SECTION K

CLIMATE

CLIMATE

Over its wide extent, the LRMA reflects the influence of a range of climates. Unfortunately, there are only two permanent stations where climatic data have been collected for more than a decade -- Fort Reliance in the northwest lies within the basin of Great Slave Lake, while Fort Smith in the southwest is on the Slave River Lowlands. Both stations are below the 200 m contour and are in the Mid Boreal Ecoregion, characterized by closed-crown Boreal forest. Therefore, they are not representative of a major part of the LRMA that rises eastward to Subarctic Woodlands at 400-500 m and then falls off through Forest Tundra and Shrub Tundra toward the Thelon Plain at 200-300 m altitude in the northeast.

Published climatic information for the area is very generalized, consisting of small-scale interpolations between the few western stations and others, such as Baker Lake, Ennadai Lake, and Churchill, that lie off the map sheet to the north, east, and south. Most of the information that follows is taken from the two-volume work of Burns (1973) and from Findlay and Treidl (1975), unless otherwise indicated.

The climate is continental subhumid, with long cold winters. Snow cover lies on the ground for 240 days at treeline and for about 40 days less in the 'warm' southwest corner near Fort Smith. Day length is reduced to four or five hours in December and January when temperature averages -25°C to -30°C . In contrast, summer days are 19 to 21 hours long between 60° and 64° latitude, giving high solar radiation (550 langleys per day in June) and daily temperatures from 21°C to 18°C (south to north) for the short growing season. Mean daily temperatures rise above 0°C about May 1 in the southwest and about May 15 near treeline. Similarly in the autumn, mean daily temperatures fall below 0°C at treeline by October 1 and at Fort Smith by October 15. Therefore, in the spring and fall, there is a difference of more than 30 days in effective growing season between the southern High Boreal and the northern High Subarctic.

According to Hare and Ritchie (1972), the Forest Tundra treeline coincides with a yearly absorbed solar radiation of 50 to 55 kilolangleys, while at the 'northern forest line' (where closed forest changes to open woodland) the value is about 80 kilolangleys. The difference is primarily due to albedo whose comparative values for typical tundra and closed-forest stations are given by

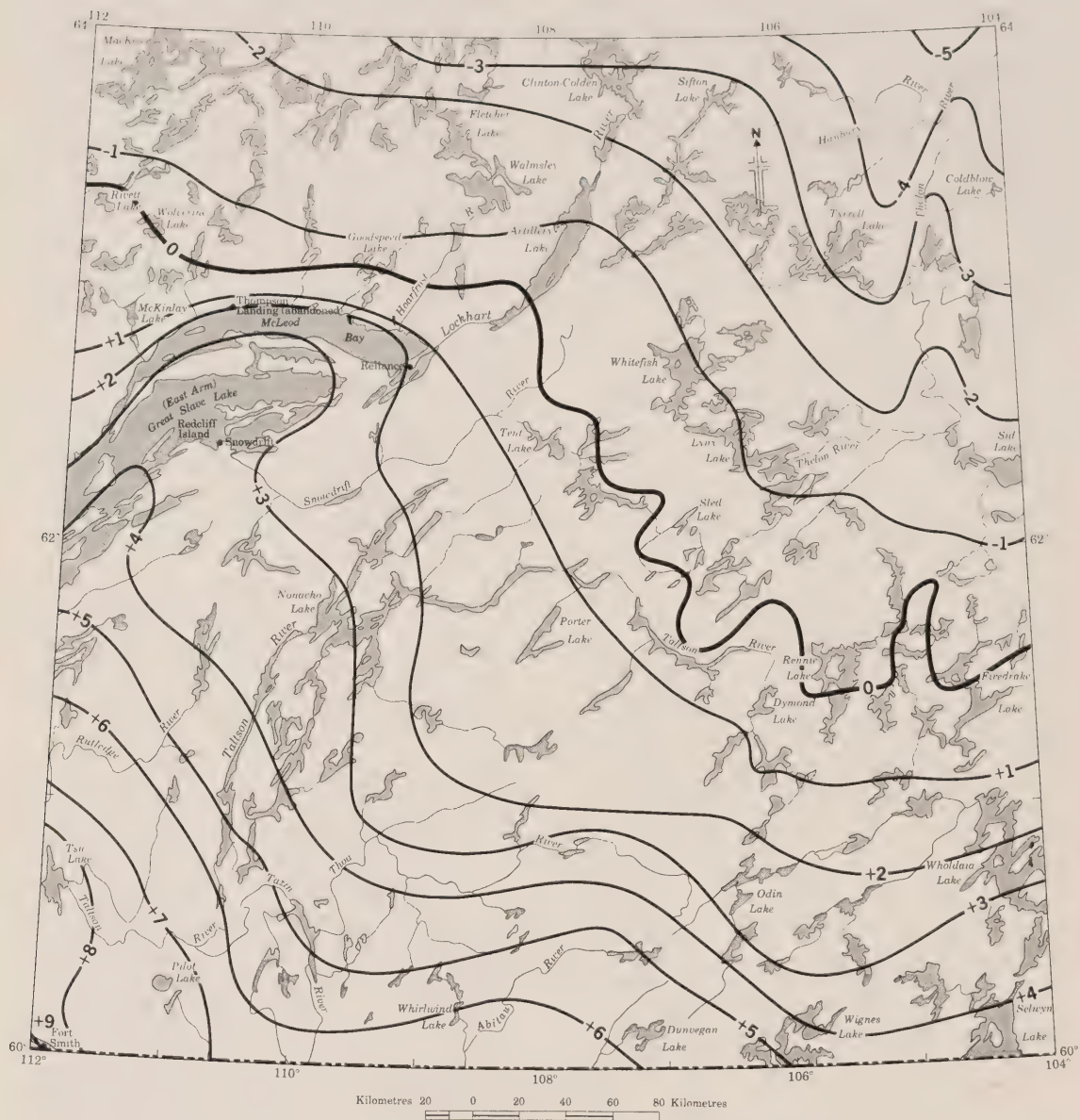
Lettau and Lettau (1973) as 0.53 and 0.24 respectively. Therefore, radiation-related parameters, such as length of frost-free season and growing degree-days, show gradient change at right angles to treeline, contouring the LRMA in a northwest to southeast direction. Brown's (1967) map, for example, places the LRMA mostly in the Discontinuous Permafrost Zone, although the northeast corner beyond Forest Tundra is shown as in the Continuous Permafrost Zone (mean annual temperature -9°C or lower) while the southwest corner is in the southern fringe of the Permafrost Region (mean annual temperature -4°C or higher).

To examine possible compensatory effects of altitude within the area, it was assumed that 'the approximate limit of trees' on the NTS maps (corresponding approximately to our Forest Tundra boundary) is a significant climatic baseline. Probable temperature differences relative to it were calculated for about 80 points throughout the LRMA, using a distance correction of 3° per degree of latitude and an altitudinal correction of 0.8°C per 100 m (the summer lapse rate, from Burns, 1973, Vol. 1:82). A contour map was then drawn, bounding areas similar in temperature differentials (Figure 12).

Although the absolute values shown are larger than can be expected in summer (due to damping by air mass climatic effects), it is the positions of the contour lines that are important. The chief indication of the map is that altitudinal differences have a limited influence on temperature regimes within the area. Mostly the contours simply parallel treeline, lending some support to the temperature-related isolines in the meteorological literature. There are a few interesting anomalies; the salients at 60° latitude, 108° longitude and at $63^{\circ}30'$ latitude, 105° longitude reflect the influences of the Abitau Highlands and the Thelon Lowlands respectively. On the former, a striking development of *Stereocaulon* Lichen Woodland is expressed, and on the latter there are relict forests of *Picea glauca*.

One further feature of the climatic maps covering the LRMA is also evident on Figure 12, namely the bending of the isolines around Great Slave Lake. This deep and large water body has a strong influence on the climate of the surrounding lands, maintaining higher than normal night temperatures during its unfrozen period so that the frost-free season in its vicinity is 100 days compared to 59 at Fort Smith three degrees of latitude farther south. The ameliorated climate is probably the most significant factor in the local

Figure 12: Theoretical mean summer temperature differences from the treeline (0) base, correcting +3°C/° latitude southward (-3°C/° latitude northward) and + 0.8°C/100 m altitude, in the LRMA



environment (the others being soil fertility and moisture), allowing the growth of closed-crown forests and the persistence of a varied Boreal flora. It should be noted, however, that the lake has a depressing effect on spring temperatures; delayed break-up makes for late springs around the East Arm where the waters are not usually clear of ice until June 30.

The total yearly precipitation is variable and low (300-400 mm), of which about half falls as snow. There are 40 to 55 days a year with measurable rainfall and 77 to 78 days with snow (figures for Fort Reliance and Fort Smith respectively). Snow depth by late winter is a relatively uniform 40-60 cm. The gradient of precipitation runs somewhat parallel to that of temperature (falling off toward treeline from southwest to northeast), but it is less marked. Limited data suggest that precipitation decreases at about 20 mm per 100 km from south to north in our area.

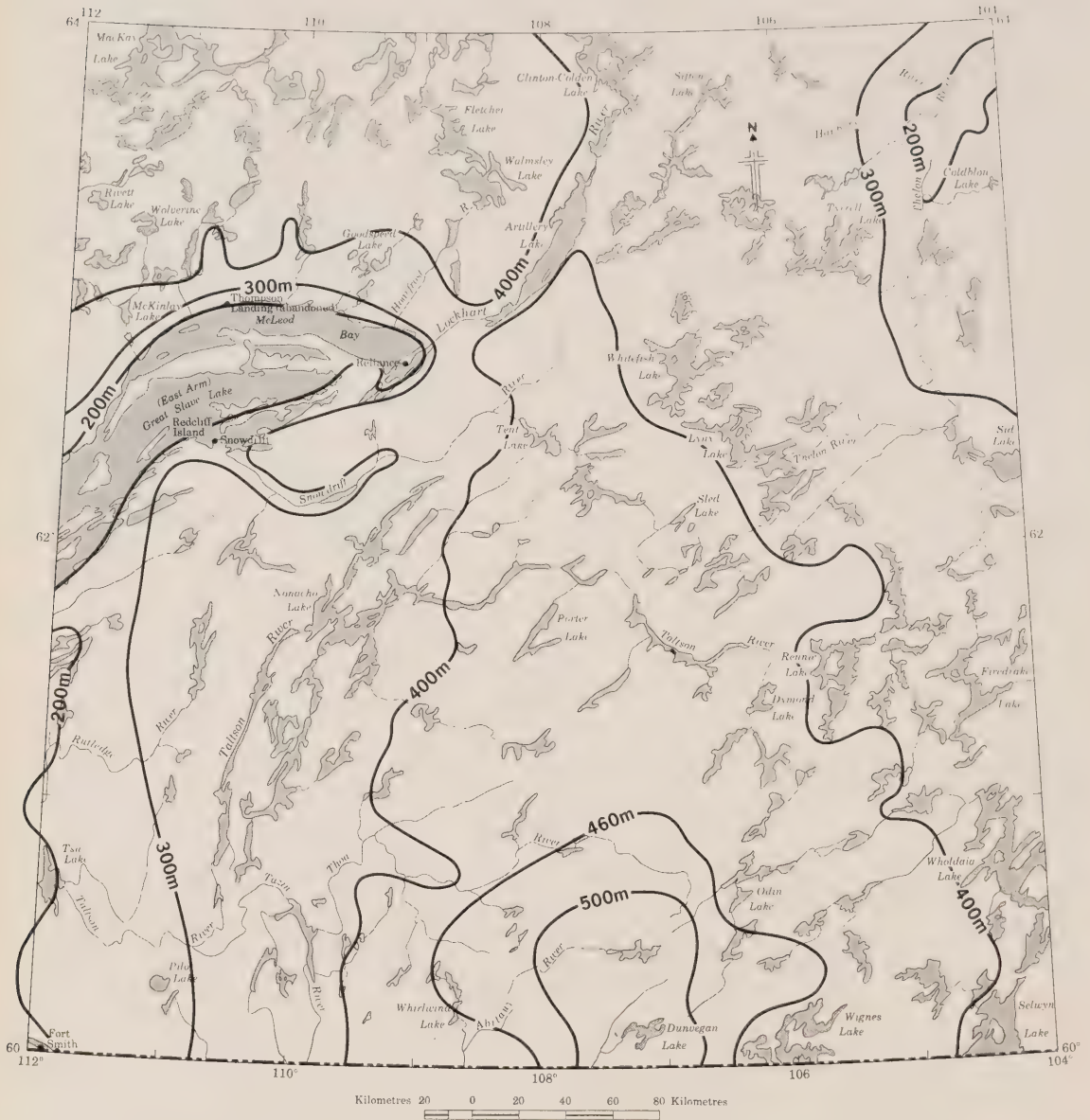
A calculation based on altitude also indicates the probability of a northward decrease in precipitation. Figure 13 shows the major contours of the LRMA, with highlands in the south-central part and lowlands to the southwest and northeast. Assuming an increase in precipitation of 25% for each 1000 feet of altitude or 8% per 100 m (Burns, 1973, Vol. 2:12), then on the Abitau Upland

300 m higher than Fort Smith (and directly east of it) the precipitation is probably about 450 mm. Northward from Abitau, toward treeline, altitude decreases and precipitation at 61°, 62°, and 63° latitude will probably be 380 mm, 300 mm, and 250 mm respectively (the last figure, at the latitude of Fort Reliance, matches the measured precipitation there). However, mean yearly evaporation decreases northward at about the same rate, from 400 mm at Fort Smith to 300 mm at Fort Reliance. Also, the influence of a permafrost table -- both an impediment to drainage and a seasonal source of moisture -- becomes more pervasive. Therefore, it is reasonable to suppose that moisture in the soil available for plant growth will be much the same throughout the LRMA. Soil moisture differences from place to place will tie closely to landform and slope position. Regional vegetation differences will relate more to radiation and temperature regimes than to the climatic moisture regime.

According to measurements in 1977, the period of terminal growth of spruces is confined to June and July at Porter Lake. The climatic warmth of these two months is probably a good index of biological potential for the LRMA. Although data are not yet available to test the temperature-treeline hypothesis, much circumstantial evidence supports it.

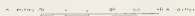
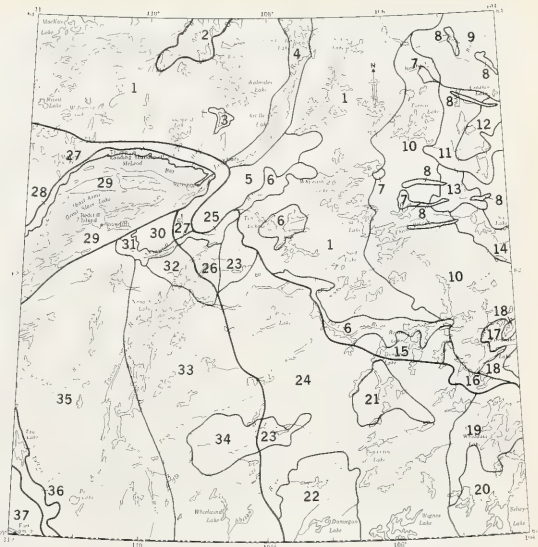
Figure 13: Map of the relief of the LRMA

Note height-of-land on the south border (+500 m) and lowlands (+200 m) in the southwest and northeast corners.



SECTION L

SOILS AND PERMAFROST



1 We2-Wo1R 2Mb-Mb1R	7 Ho1-Ly1 Fr-Mb	13 Ly1 1Mb	19 Pol1Dy1 2Mb1Ob	25 Pol1Dy1 1Mb1F	31 Na1Snl 1Mb1F
2 Wo1-Wo2 2Mb1Mb	8 Ho1 Fr	14 Ly1 2Mb	20 Pol1Dy1 1Mb1Ob	26 Pol1Dy1 2Mb1Ob	32 Na1Tal 2Mb1Ob
3 Wo1 2Mb	9 Co1-Co2 Mb-Mb	15 Wo1-Mb1 2Mb1Fr	21 Pol1Dy1 1Mb1Ob	27 Na2IR 2Mb1R	33 Na2Mb1Ob 2Mb1R
4 Wo1-Wo2 1Mb1Mb	10 Ly1-Ly2R 2Mb1Mb1R	16 Wo1S1 1Mb1Ob	22 Po2-Po1Dy1 2Mb1Fr-Mb1Ob	28 Na2IR 2Mb1R	34 Na1 2Mb
5 Wo2IR 2Mb1R	11 Co1 1Mb	17 Ly1S1 1Mb1Ob	23 Po1 2Mb1R	29 Na2IR 2Mb1R	35 Na2IR 2Mb1R
6 Wo1 1Mb	12 Co1 2Mb	18 Ly1 Mb	24 Pol1Dy1 2Mb1Fr1Ob	30 Na1IR 2Mb1R	36 Na2IR 2Mb1R
				37 Pol1Na1 1Mb1R	

SOIL ASSOCIATIONS AND GENETIC SOIL NAMES

MATERIAL	HIGH SUBARCTIC	LOW SUBARCTIC	HIGH & MID BOREAL
	Wolverine Lake 1 EDB, ODB*, GDB*, GTC+ 3 2 2 3	Porter Lake 1 EDB, GDB, RG+ 6 1 3	Nonacho Lake 1 EDB, GDB, RG+ 6 1 3
TILL	Lynx Lake 1 EDB, ODB*, GDB*, GTC+ 3 2 2 3		
	Coldflow Lake 1 EDB*, OTC, GTC+ 5 3 2		
	Wolverine Lake 7 EDB*, ODB*, GDB*, GTC+ 4 2 2 2	Porter Lake 2 EDB, GDB*, RG+ 7 1 2	Nonacho Lake 2 EDB, GDB*, RG+ 6 1 3
SHALLOW TILL OVER BEDROCK	Lynx Lake 2 EDB*, ODB*, GDB*, GTC+ 4 2 2 2	Orin Lake 1 EDB, GDB, RG+ 7 1 2	Snowdrift River 1 EDB, GDB, RG+ 7 1 2
	Coldflow Lake 2 EDB*, ODB*, GDB*, GTC+ 4 2 2 2		
ICE CONTACT & FLUVIAL	Snowdrift River 1 EDB, ODB, GDB, GTC+ 4 2 2 2	Orin Lake 1 EDB, GDB, RG+ 7 1 2	Snowdrift River 1 EDB, GDB, RG+ 7 1 2
LACUSTRINE			Redcliff Island 1 OTC, GTC 8 4
			Fort Smith 1 OEB, EEB, GEB, RG+ 7 1 2
ALLUVIUM			Northstar 1 OR, CR, RG+ 8
PEAT	Sigd Lake 1 MOC, FOC 7 3	Diamond Lake 1 MOC, FOC 7 3	Talton River 1 MOC, FOC 7 3

*Cryoturbic phase

+ Peaty phase

± Lithic phase

Numbers below genetic soil symbols indicate, by a dot number, the percentage of each drainage class represented by the soils in each map cell. e.g. EDB—Elevated Dystric Brunisol, well drained, 30%.

Genetic Soil Names, Symbols and Drainages

Brunisols, well drained	ODB—Orthic Dystric	OEB—Orthic Eutric
imperfectly drained	EDB—Elevated Dystric	EEB—Elevated Eutric
	GDB—Gleysolic Dystric	GEB—Gleysolic Eutric
Regosols, well drained	OR—Orthic	CR—Cumulic
Cryosols imperfectly to poorly drained	OTC—Orthic Turbic	FOC—Fibric Organic
Gleysols, poorly drained	GTC—Gleysolic Turbic	MOC—Mesic Organic
	RG—Rego	

SOILS AND PERMAFROST

1. DISTRIBUTION OF SOILS

The Lockhart River Map Area is dominated by Brunisolic soils (Figure 14). Eluviated Dystric Brunisols and Orthic Dystric Brunisols (Canada Soil Survey Committee, 1978) are the most common types, except in the Slave River Lowlands, where some Eluviated Eutric Brunisols are found. Brunisols developed on glacial till materials in the northern part of the map (the area north of the Great Slave, Eileen, Rennie, and Wholdaia lakes) are affected by cryoturbation. These cryoturbated Brunisols are associated with various amounts of Turbic and Organic Cryosols. In the southern part of the area, Eluviated Dystric Brunisols and Orthic Dystric Brunisols are commonly associated with Organic Cryosols and Gleysols. A noticeably higher amount of Organic Cryosols was found in the southeastern portion of the map area, around Wholdaia Lake.

Brunisols in the area of Great Slave Lake are associated with Turbic Cryosols. These Turbic Cryosols have developed on fine-textured lacustrine deposits and are associated with earth hummocks. The southwestern part of the area, south of Great Slave Lake, has a bedrock-dominated terrain. Here, Brunisols occur on patchy, thin till areas, while Organic Cryosols have developed on peat deposits in depressions.

Poorly drained areas are associated with Gleysolic soils in the southern portion of the map area and with Gleysolic Turbic Cryosols in the northern part. All poorly drained soils have a peaty surface layer of varying thickness.

The extreme southwestern corner of the map, in the vicinity of Fort Smith, is dominated by Eluviated Eutric Brunisols, Orthic Regosols, and Rego Gleysols.

2. SOIL DEVELOPMENT

The LRMA is situated in the Subarctic and the northern part of the Boreal regions. The climate is characterized by cold temperatures and low precipitation. The dominant parent materials of mineral soils in the area are coarse-textured glacial till and ice-contact material. On these parent materials, podzolization and cryogenic processes dominate the soil development.

As a result of the weak podzolization process, removal of materials by leaching produces an Ae horizon, while the addition of

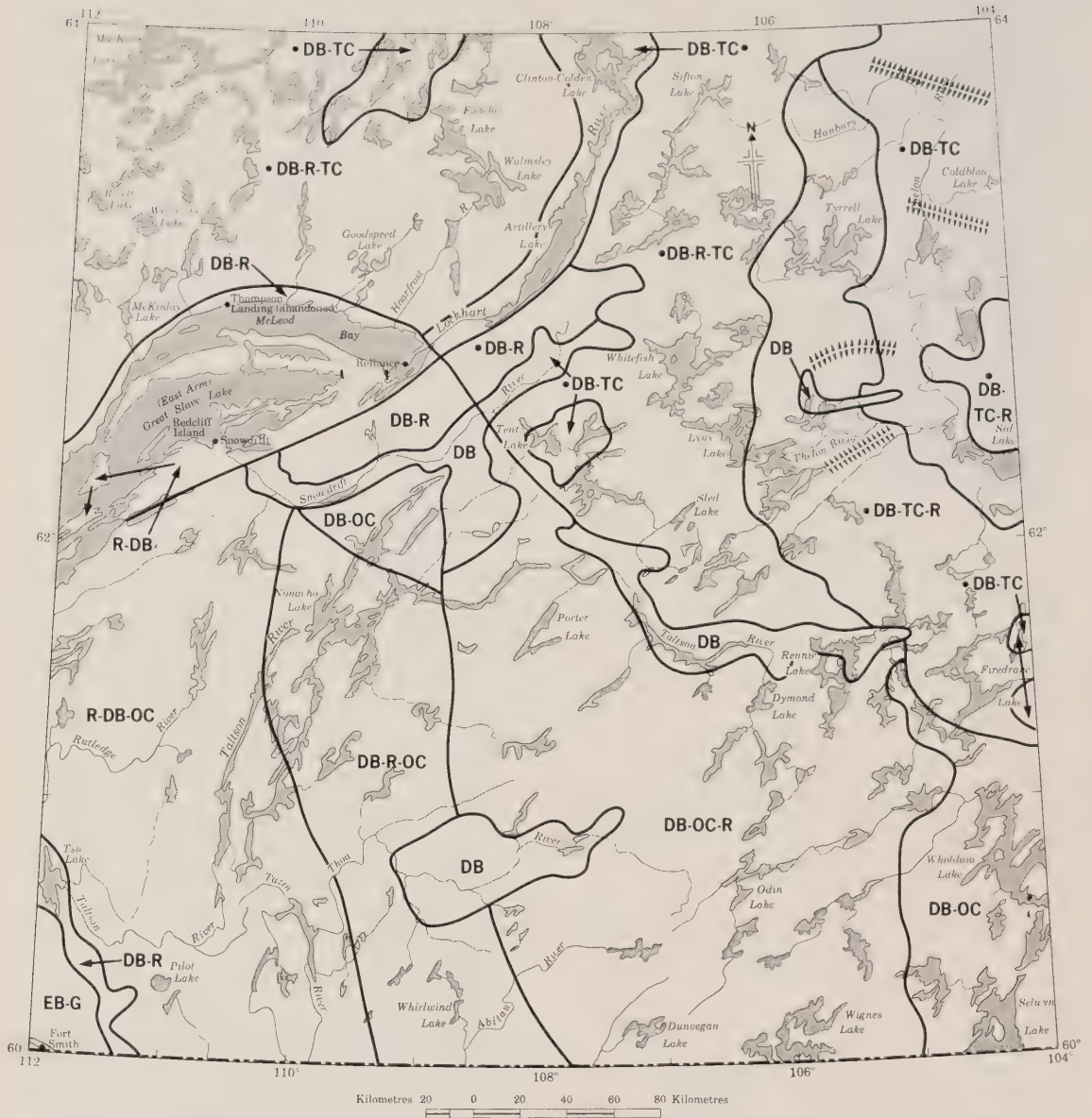
materials produces a brownish B horizon. This brownish Bm or Bfj horizon is commonly found throughout the map area. The Ae horizon, on the other hand, occurs commonly in the south (Boreal Forest and continuous Lichen Woodland areas) but is somewhat less common in the north.

Some of the Brunisols in the Porter Lake area have a well-developed Bm or Bfj horizon which is generally associated with a weakly cemented layer. The best developed B horizon was found on a soil situated near the top of the kame in the Porter Lake area. This soil (sandy in texture) was classified as Orthic Humic Podzol, having pyrophosphate-extractable Fe + Al of 0.43%, moist colour of 2.5YR 3/4, and organic carbon content of 0.8% in the Bf horizon.

Well-drained mineral soils developed on glacial till north of the continuous Lichen Woodland (north of Great Slave, Eileen, Rennie, and Wholdaia lakes, approximately) are affected by cryoturbation. The most commonly occurring morphological results of cryoturbation are disrupted soil horizons and patterned ground. Although cryoturbation and patterned ground are present in these soils, the permafrost table is well below the control section. Data from the Lynx Lake area (Figure 15) indicate that the frost table is well below the 2 m control section since no frost table was found in the soil pit at a depth of 2.05 m on August 21, 1977. The soil temperature at a depth of 150 cm was about 4°C at site DP2 (Orthic Dystric Brunisol) and 3°C at site DP3 (Dystric Brunisol, cryoturbic phase). Shallow soils having the lithic contact within the control section (e.g., site DP1, Figure 15) are strongly cryoturbated since bedrock acts as a solid layer (similar to permafrost) allowing cryoturbation to operate. On deep soils, since there is no solid contact (i.e., no permafrost table or lithic layer), it is not clear how cryoturbation operates. One can speculate either that the frost table is high during certain years and this is when cryoturbation is active or that the frost table rises quickly during early fall and, thus, cryoturbation can operate. Another possibility is that, in some cases, we may be dealing with a fossil form, developed under a cooler climate when the situation was favourable for cryoturbation.

Most of these cryoturbated Brunisols and Turbic Cryosols, especially those associated with patterned ground, have a characteristic vesicular poor structure and unstable thixotropic properties. This thixotropic phenomenon is commonly found in the Canadian

Figure 14: Distribution of soils in the LRMA



DB DYSTRIC BRUNISOL

EB EUTRIC BRUNISOL

TC TURBIC CRYOSOL

OC ORGANIC CRYOSOL

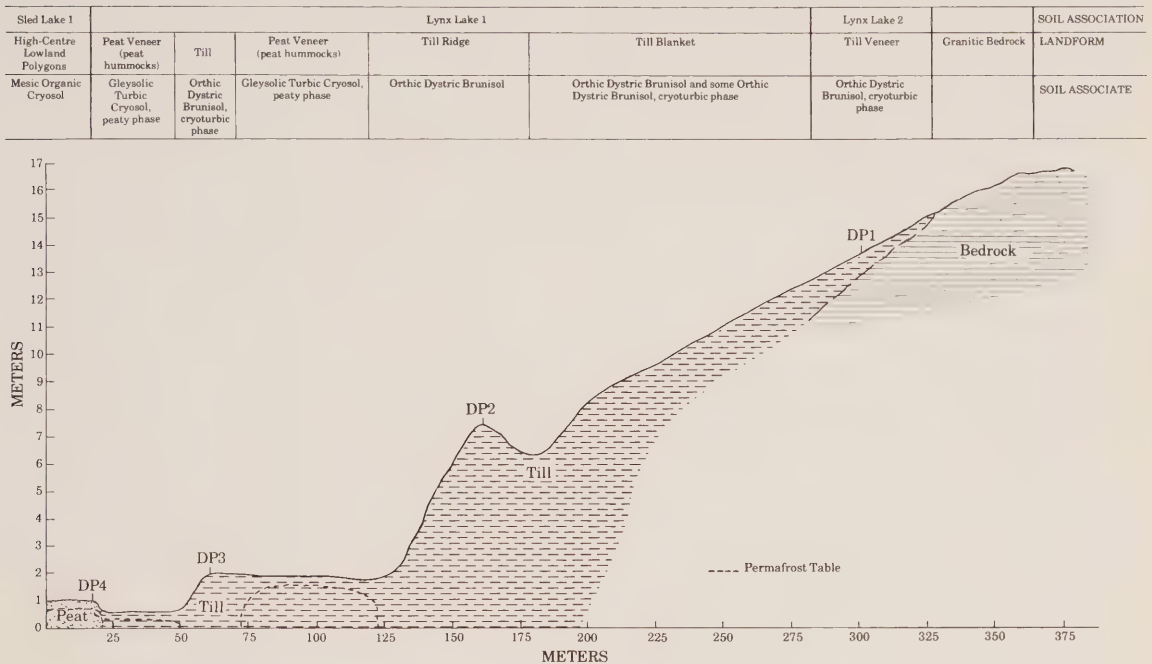
G GLEYSOL

R ROCKLAND

MAJOR ESKE

• SOILS AFFECTED BY CRYOTURBATION (CRYOTURBIC PHASE)

Figure 15: Cross-section showing soil associations, parent materials, soil types, distribution of permafrost, and the locations of sample sites. Surveyed August 22, 1977, Lynx Lake area, 106°05' longitude, 62°23' latitude.



north (Bunting and Fedoroff, 1973; Tarnocai, 1976; Woo and Zoltai, 1977) and indicates the unstable system produced when, due to mechanical disturbance, liquification takes place.

Poorly drained mineral terrain is generally associated with Gleysolic Turbic Cryosols to the north of the Lichen Woodland area and with Gleysols to the south. All of these soils have a well-developed surface peat layer. The Gleysolic Turbic Cryosols are cryoturbated and are associated with various amounts of ground ice.

Soils developed on peat deposits are generally perennially frozen (Organic Cryosols). The most common peat landforms associated with these soils are palsas, peat plateaus, polygonal peat plateaus, and, in northern areas, high-center lowland polygons (Tarnocai, 1970; Zoltai and Tarnocai, 1975). Most of these Organic Cryosols have developed from mesic and fibric peat materials and contain high amounts of ground ice. Some of these soils are strongly eroding, especially those adjacent to lakeshores and streams, while some polygonal peat plateaus and high-

center lowland polygons are affected by wind erosion.

All Cryosols in the study area contain various amounts of ice. This ice is present in the form of segregated ice crystals, vein ice, ice lenses, and ice wedges. The ice content of the coarse-textured mineral Cryosols in the area is generally low. Fine-textured mineral Cryosols occur in the vicinity of Great Slave Lake and have developed on lacustrine materials associated with moderate amounts of ice. Organic Cryosols contain large amounts of ice, not only in the form of ice crystals and ice lenses but also in the form of massive ice wedges.

3. DESCRIPTION OF SOIL ASSOCIATIONS

A brief description of the soil associations is presented in Table 4 while more detailed information is given, according to each soil association, in this section.

Soils were mapped as soil associations. A soil association is a sequence of soils of approximately the same age which have

Table 4: Description of soil associations

Map Symbol	Eco-region	Soil Association	Parent Material	Ground Ice, Ice Content and Patterned Ground	Gen. Name and Drainage*
Wo1	High Subarctic	Wolverine Lake 1	Noncalcareous sandy loam and loamy sand glacial till derived mainly from granitic rocks.	Material associated with Cryosolic soils has segregated ice crystals, vein ice, and some ice lenses. Low ice content. Non-sorted circles	Eluviated Dystric Brunisol (W3) Orthic Dystric Brunisol, cryoturbic phase (W2)* Gleyed Dystric Brunisol, cryoturbic phase (I2) Gleysolic Turbic Cryosol, peaty phase (P3)
Wo2		Wolverine Lake 2	Less than 1 m of noncalcareous sandy loam and loamy sand glacial till derived mainly from granitic rocks over bedrock	Material associated with Cryosolic soils has segregated ice crystals. Low ice content. Non-sorted circles.	Eluviated Dystric Brunisol, cryoturbic phase (W4) Orthic Dystric Brunisol, cryoturbic phase (W2) Gleyed Dystric Brunisol, cryoturbic phase (I2) Gleysolic Turbic Cryosol, peaty phase (P2)
Ly1		Lynx Lake 1	Noncalcareous loamy sand and sand glacial till derived mainly from sandstone.	Material associated with Cryosolic soils has segregated ice crystals, vein ice, and some ice lenses. Low ice content. Non-sorted circles.	Eluviated Dystric Brunisol (W3) Orthic Dystric Brunisol, cryoturbic phase (W2) Gleyed Dystric Brunisol, cryoturbic phase (I2) Gleysolic Turbic Cryosol, peaty phase (P3)
Ly2		Lynx Lake 2	Less than 1 m of noncalcareous loamy sand and sand glacial till derived mainly from sandstone over bedrock.	Material associated with Cryosolic soils has segregated ice crystals. Low ice content. Non-sorted circles.	Eluviated Dystric Brunisol, cryoturbic phase (W4) Orthic Dystric Brunisol, cryoturbic phase (W2) Gleyed Dystric Brunisol, cryoturbic phase (I2) Gleysolic Turbic Cryosol, peaty phase (P2)
Co1		Coldblow Lake 1	Noncalcareous sandy loam to sand glacial till derived mainly from red sandstone.	Material associated with Cryosolic soils has segregated ice crystals, vein ice, and some ice lenses. Low ice content. Non-sorted circles.	Eluviated Dystric Brunisol, cryoturbic phase (W5) Orthic Turbic Cryosol (W,I3) Gleysolic Turbic Cryosol, peaty phase (P2)
Co2		Coldblow Lake 2	Less than 1 m of noncalcareous sandy loam to sand glacial till derived from red sandstone over bedrock	Material associated with Cryosolic soils has segregated ice crystals, vein ice, and some ice lenses. Low ice content. Non-sorted circles.	Eluviated Dystric Brunisol, cryoturbic phase (W4) Orthic Dystric Brunisol, cryoturbic phase (W2) Gleyed Dystric Brunisol, cryoturbic phase (I2) Gleysolic Turbic Cryosol, peaty phase (P2)
Ho1		Hoarfrost River 1	Noncalcareous sand and gravel, ice contact and fluvial materials.	Material associated with Cryosolic soils has segregated ice crystals. Low ice content. No patterned ground.	Eluviated Dystric Brunisol (W4) Orthic Dystric Brunisol (W2) Gleyed Dystric Brunisol (I2) Gleysolic Turbic Cryosol, peaty phase (P2)
SI1		Sled Lake 1	Deep fibric and mesic peat materials.	Segregated ice crystals, vein ice, ice lenses, and ice wedges. Medium to high ice content. Polygonal peat plateaus and lowland high center polygons.	Mesic Organic Cryosol (W,I7) Fibric Organic Cryosol (W,I3)
Po1	Low Subarctic	Porter Lake 1	Noncalcareous sandy loam and loamy sand glacial till derived mainly from granitic rocks.	No ground ice in the near surface. No patterned ground.	Eluviated Dystric Brunisol (W6) Gleyed Dystric Brunisol (I1) Rego Gleysol, peaty phase (P3)
Po2		Porter Lake 2	Less than 1 m of noncalcareous sandy loam and loamy sand glacial till derived mainly from granitic rocks	No ground ice. No patterned ground.	Eluviated Dystric Brunisol, lithic phase (W7) Gleyed Dystric Brunisol, lithic phase (I1) Rego Gleysol, peaty phase (P2)
Od1		Odin Lake 1	Noncalcareous sand and gravel, ice contact and fluvial materials.	No ground ice in the near surface. No patterned ground.	Eluviated Dystric Brunisol (W7) Gleyed Dystric Brunisol (I1) Rego Gleysol, peaty phase (P2)
Dy1		Dymond Lake 1	Deep fibric sphagnum and mesic forest and/or fen peat.	Segregated ice crystals, vein ice, and ice lenses. Medium to high ice content. Peat plateaus and palsas.	Mesic Organic Cryosol (W,I7) Fibric Organic Cryosol (W,I3)
Na1	High and Mid Boreal	Nonacho Lake 1	Noncalcareous sandy loam and loamy sand glacial till derived mainly from granitic rocks.	No ground ice. No patterned ground.	Eluviated Dystric Brunisol (W6) Gleyed Dystric Brunisol (I1) Rego Gleysol, peaty phase (P3)
Na2		Nonacho Lake 2	Less than 1 m of noncalcareous sandy loam and loamy sand glacial till derived mainly from granitic rocks.	No ground ice. No patterned ground.	Eluviated Dystric Brunisol, lithic phase (W6) Gleyed Dystric Brunisol, lithic phase (I1) Rego Gleysol, peaty phase (P3)
Sn1		Snowdrift River 1	Noncalcareous sand and gravel, ice contact and fluvial materials.	No ground ice. No patterned ground.	Eluviated Dystric Brunisol (W7) Gleyed Dystric Brunisol (I1) Rego Gleysol, peaty phase (P2)
Re1		Redcliff Island 1	Noncalcareous clay loam to clay lacustrine deposits.	Segregated ice crystals, vein ice, and ice lenses. Medium to high ice content. Earth hummocks.	Orthic Turbic Cryosol (W,I6) Gleysolic Turbic Cryosol (P4)
Ta1		Taltson River 1	Deep fibric sphagnum and mesic forest and/or fen peat.	Segregated ice crystals, vein ice, and ice lenses. Medium to high ice content. Peat plateaus and palsas	Mesic Organic Cryosol (W,I7) Fibric Organic Cryosol (W,I3)
Fo1		Fort Smith 1	Weakly calcareous sandy to loamy lacustrine or deltaic materials	No ground ice. No patterned ground	Orthic Eutric Brunisol } (W7) Eluviated Eutric Brunisol } Gleyed Eutric Brunisol (I1) Rego Gleysol, peaty phase (P2)
No1		Norberta 1	Weakly calcareous sand to loamy sand alluvium.	No ground ice. No patterned ground.	Orthic Regosol } (W2) Cumulic Regosol } Rego Gleysol, peaty phase (P8)

* Symbols are: W – well-drained; I – imperfectly drained; P – poorly drained.
Numbers following symbols are tenths of area covered; e.g. W3 – 30% well-drained.

developed on parent material of similar origin and physical and chemical characteristics, but which have unlike genetic characteristics because of variation in relief and drainage. The soil association is restricted to a specific climate (ecoregion) and condition, and the names of the soil association do not cross ecoregion boundaries. The same soil association may occur, however, on similar parent materials in several different ecodistricts within the same ecoregion.

WOLVERINE LAKE 1 ASSOCIATION (Map Symbol Wo1)

Characteristic till soils in ecodistricts HS_{ST}³, HS_{ST}⁴, HS_{FT}⁵, and HS_{FT}.

Wolverine Lake 1 association consists of well-drained Eluviated Dystric Brunisol and Orthic Dystric Brunisol, cryoturbic phase, imperfectly drained Gleyed Dystric Brunisol, cryoturbic phase, and poorly drained Gleysolic Turbic Cryosol, peaty phase. These soils have developed on deep, stony, noncalcareous glacial till which is derived mainly from granitic rocks. The texture of this glacial till is sandy loam to loamy sand (Table 5).

Although a majority of the soils in this soil association are affected by cryoturbation (indicated by disrupted soil horizons and intrusions of materials into other horizons), some of the well-drained soils are completely free of cryoturbation. All of these soils have well-developed Bm or Bg horizons. The poorly drained associates have the permafrost table within the control section and their perennially frozen horizons are associated with segregated ice crystals, vein ice, and some ice lenses. Most of the cryoturbated Brunisols and Turbic Cryosols, especially those associated with patterned ground, have thixotropic properties. In these soils, liquification takes place due to mechanical disturbance.

The topography is rolling with low hills and valleys, and the terrain is spotted with numerous lakes and ponds. The associated patterned ground types are nonsorted circles and nonsorted nets. The vegetation is Heath-Lichen or Shrub-Heath on well-to-imperfectly drained areas and Sedge Meadow on poorly drained locations. Patches of stunted black spruce may occur on slopes and along drainages.

The soil characteristics of an Orthic Dystric Brunisol, cryoturbic phase, are given in Table 6.

WOLVERINE LAKE 2 ASSOCIATION (Map Symbol Wo2)

Characteristic shallow till soils in ecodistricts HS_{ST}³, HS_{ST}⁴, HS_{FT}⁵, and HS_{FT}⁶.

The soils of this association and their parent materials are very similar to those of the Wolverine Lake 1 association. The parent material, however, is shallow (less than 1 m) and the bedrock, being a permanent hard surface, behaves in a manner similar to the permafrost table with the result that all of the soils are affected by cryoturbation. Most of the cryoturbated Brunisols and Turbic Cryosols, especially those associated with patterned ground, have thixotropic properties. In these soils, liquification takes place due to mechanical disturbance.

The topography is rolling to hilly with numerous bedrock outcrops. Lakes and ponds are common. The associated patterned ground types are nonsorted circles and nonsorted steps. The vegetation is Heath-Lichen or Shrub-Heath on well-to-imperfectly drained areas and Sedge Meadow on poorly drained locations. Patches of stunted black spruce may occur on slopes and along drainages.

LYNX LAKE 1 ASSOCIATION (Map Symbol Ly1)

Characteristic till soils in ecodistrict HS_{ST}².

Lynx Lake 1 association consists of well-drained Eluviated Dystric Brunisol, Orthic Dystric Brunisol, Orthic Dystric Brunisol, cryoturbic phase, and poorly drained Gleysolic Turbic Cryosol, peaty phase. These soils have developed on deep, stony, noncalcareous glacial till which is derived mainly from pale yellow Dubawnt sandstone.

Although a majority of the soils in this association are affected by cryoturbation (indicated by disrupted soil horizons and intrusions of materials into other horizons), some of the well-drained soils are completely free of cryoturbation. All of these soils have moderately well-developed Bm or Bg horizons. The poorly drained associates have permafrost tables within the control section and their perennially frozen horizons are associated with segregated ice crystals. Most of the cryoturbated Brunisols and Turbic Cryosols, especially those associated with patterned ground, have thixotropic properties. In these soils, liquification takes place due to mechanical disturbance.

The topography is rolling with low hills and valleys and the terrain is spotted with

Table 5: Physical and chemical composition of till materials

Material	Sample No.	Textural Class	Very Coarse Sand %	Coarse Sand %	Medium Sand %	Fine Sand %	Very Fine Sand %	Total Sand %	Silt %	Clay %	pH	Stones %
Coldblow Lake Till (red till)	P41	LS	5	10	23	30	16	84	14	2	5.1	27
	P42	S	5	12	25	31	15	88	11	1	4.7	16
	P43	SL	5	4	7	19	22	57	38	5	5.9	20
Lynx Lake Till (sandstone till)	P19	LS	15	15	15	16	11	72	26	2	5.1	35
	P20	LS	4	12	25	25	15	81	16	33	4.9	15
	P45	S	5	10	24	32	16	87	11	2	5.1	12
	DP1	SL	2	10	21	20	11	64	35	1	4.8	7
	DP2	LS	2	9	27	31	12	81	19	0	6.3	5
	DP3	LS	2	9	34	28	9	82	16	2	4.7	6
Wolverine Lake Till (granitic till)	P7	SL	7	8	13	26	15	69	24	7	4.6	6
	P8	SL	—	1	2	14	32	49	49	2	4.4	1
	P13	SL	9	8	8	12	18	55	42	3	4.5	13
	P14	LS	10	11	15	22	17	75	21	4	4.7	32
	P34	SL	17	9	10	15	15	66	31	3	5.6	25
	P35	SL	4	3	7	18	16	48	47	5	5.6	4
	P37	LS	17	13	13	17	15	75	24	1	5.7	24
Porter Lake Till (granitic till)	P4	LS	7	10	21	29	18	85	14	1	5.5	30
	P6	LS	4	8	26	33	14	85	13	2	5.4	12
	P49	SL	7	9	15	20	14	65	32	3	5.6	4

numerous lakes and ponds. The associated patterned ground types are nonsorted circles and nonsorted nets. The vegetation is Heath-Lichen or Shrub-Heath on well-to-imperfectly drained areas and Sedge Meadow on poorly drained locations.

Soil characteristics of the Eluviated Dystric Brunisol, Orthic Dystric Brunisol, and Orthic Dystric Brunisol, cryoturbic phase, are given in Tables 7, 8, and 9 respectively.

LYNX LAKE 2 ASSOCIATION (Map Symbol Ly2)

Soils in ecodistrict HS_{ST}².

The soils of this association and their parent materials are very similar to those of the Lynx Lake 1 association. The parent material, however, is shallow (less than 1 m) and the bedrock, being a permanent hard surface, behaves in a manner similar to the permafrost frost table with the result that all of the soils are affected by cryoturbation. Most of the cryoturbated Brunisols and Turbic Cryosols, especially those associated with patterned ground, have thixotropic properties. In these soils, liquification takes place due to mechanical disturbance.

The topography is rolling to hilly with numerous bedrock outcrops. Lakes and ponds are common. The associated patterned ground types are nonsorted circles and nonsorted steps. The vegetation is Heath-Lichen or Shrub-Heath on well-to-imperfectly drained areas and Sedge Meadow on poorly drained locations. Patches of stunted black spruce may occur on slopes and along drainages.

Soil characteristics of an Orthic Dystric Brunisol, cryoturbic phase, are given in Table 10. The location of this site is indicated on a cross-section (Figure 15).

COLDBLOW LAKE 1 ASSOCIATION (Map Symbol Col1)

Characteristic soils in ecodistrict HS_{ST}¹.

Coldblow Lake 1 association consists of well-drained Eluviated Dystric Brunisol, cryoturbic phase, Orthic Turbic Cryosol, and poorly drained Gleysolic Turbic Cryosol, peaty phase. These soils have been developed on deep, stony, noncalcareous glacial till which is derived mainly from reddish Dubawnt sandstone. The texture of this till is sandy loam to sand (Table 4).

Table 6: Wolverine Lake 1 association: morphological description and physical and chemical analyses of an Orthic Dystric Brunisol, cryoturbic phase (P35)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Ah	0- 3	—	SL	Structureless Single grain	Nonsticky Nonplastic	Clear Broken	Plentiful	Very few	None
Bmy	3-24	10YR 5/6	SL			Clear Wavy	Few	Few	Medium
Cy	24+	10YR 7/4	SL			—	Few	Very few	Medium

Physical and Chemical Analyses

Horizon	Depth (cm)	Stones		Sand %	Silt %	Clay %	pH	Org. C %	N %	C:N Ratio	Exchange Analysis (meq/100 g)					
		Dominant Size (cm)	%								Ca	Mg	K	Na	H	CEC
Ah	0- 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bmy	3-24	0.2-2	33	68	30	2	5.4	0.4	Tr	—	0.1	Tr	Tr	Tr	3.7	3.8
Cy	24+	0.2-0.5	4	48	47	5	5.6	—	—	—	0.3	Tr	Tr	Tr	2.2	2.5

Tr: less than 0.1

Table 7: Lynx Lake 1 association: morphological description and physical and chemical analyses of an Eluviated Dystric Brunisol (P20)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Ah	0- 4	2.5YR 2.5/0	LS			Clear Broken	Plentiful	—	None
Ae	4-13	10YR 7/2	LS			Abrupt Irregular	Few	Few	None
Bfj	13-20	5YR 3/4	LS	Structureless Single grain	Nonsticky Nonplastic	Gradual Wavy	Few	Very few	None
BC	20-30	10YR 6/6	LS			Gradual Wavy	None	—	None
C	30-50	7.5YR 6/2	LS				None	—	None

Physical and Chemical Analyses

Horizon	Depth (cm)	Stones		Sand %	Silt %	Clay %	pH	Org. C %	N %	C:N Ratio	Exchange Analysis (meq/100 g)					
		Dominant Size (cm)	%								Ca	Mg	K	Na	H	CEC
Ah	0- 4	0.5-1 2.5+	12	85	7	8	3.0	13.7	0.5	27	2.4	0.1	0.4	0.2	49.0	51.5
Ae	4-13	0.2-0.5	4	74	25	1	3.9	0.2	Tr	—	0.1	Tr	Tr	0.1	1.3	1.5
Bfj	13-20	0.2-0.5	7	80	18	2	4.4	1.3	0.1	13	0.4	0.1	Tr	0.1	9.8	10.3
BC	20-30	0.5-1	10	76	21	3	4.8	0.3	Tr	—	0.1	Tr	Tr	Tr	2.3	2.0
C	30-50	0.2-0.5 3.5+	15	81	16	3	4.9	—	—	—	0.1	Tr	Tr	Tr	0.7	0.8

Tr: less than 0.1

Table 8: Lynx Lake 1 association: morphological description and physical and chemical analyses of an Orthic Dystric Brunisol (DP2)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Ah	0- 2	10YR 5/2	LS	Structureless Single grain	Nonsticky Nonplastic	Clear Broken	Plentiful	—	None
Bm	2- 18	7.5YR 5/6	LS			Clear Wavy	Few	—	None
BC	18- 35	10YR 7/4	S			Gradual Wavy	Very few	—	None
C	35-150	10YR 7/2	LS				None	—	None

Physical and Chemical Analyses

Horizon	Depth (cm)	Stones		Sand %	Silt %	Clay %	pH	Org. C %	N %	C:N Ratio	Exchange Analysis (meq/100 g)					
		Dominant Size (cm)	%								Ca	Mg	K	Na	H	CEC
Ah	0- 2	0.5-1 3+	31	85	13	2	4.2	3.6	0.2	18	0.7	2.0	0.1	0.1	8.4	11.5
Bm	2- 18	0.5-1 3.5+	45	84	13	3	4.9	0.7	Tr		0.1	Tr	Tr	Tr	5.5	5.8
BC	18- 35	0.5-1 3+	9	85	15	0	5.3	0.1			0.1	Tr	Tr	Tr	1.0	1.2
C	35-150	0.5-1 3+	5	81	19	0	6.3	—			0.2	Tr	Tr	Tr	0.5	0.6

Tr: less than 0.1

Table 9: Lynx Lake 1 association: morphological description and physical and chemical analyses of an Orthic Dystric Brunisol, cryoturbic phase (DP3)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Cy1	0-29	10YR 5/4	SL	Structureless Single grain	Nonsticky Nonplastic	Gradual Wavy	Few	Vesicular	Strong
Cy2	29- 52	10YR 6/3	SL			Clear Wavy	Few	Vesicular	Strong
Ahb	52- 73	10YR 4/2	SL			Clear Wavy	Very few	Few	None
Bmb	73-100	7.5YR 4/4	SL			Gradual Wavy	None	Few	None
BCb	100-205	10YR 5/4	LS			—	None	Very few	None

Physical and Chemical Analyses

Horizon	Depth (cm)	Stones		Sand %	Silt %	Clay %	pH	Org. C %	N %	C:N Ratio	Exchange Analysis (meq/100 g)					
		Dominant Size (cm)	%								Ca	Mg	K	Na	H	CEC
Cy1	0- 29	0.2-0.5	2	54	43	3	5.2	0.2	Tr	—	0.3	0.1	Tr	Tr	1.7	2.1
Cy2	29- 52	0.5-1	3	55	43	2	4.8	0.2	Tr	—	0.2	Tr	Tr	Tr	2.0	2.2
Ahb	52- 73	0.5-1	3	55	38	7	4.6	1.6	Tr	—	0.5	0.1	Tr	Tr	6.7	7.3
Bmb	73-100	0.5-1 3+	21	71	25	4	4.7	0.5	Tr	—	0.3	0.1	Tr	Tr	4.7	5.1
BCb	100-205	0.2-0.5	6	82	16	2	4.7	0.1	—	—	0.1	0.2	Tr	Tr	1.6	1.9

Tr: less than 0.1

Table 10: Lynx Lake 2 association: morphological description and physical and chemical analyses of an Orthic Dystric Brunisol, cryoturbic phase (DP1)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Ah	—	5YR 3/2	S			Clear Wavy	Plentiful	—	None
Bmy1	—	5YR 3.5/3.5	LS	Structureless Single grain	Nonsticky Nonplastic	Gradual Wavy	Few	Vesicular	Strong
Bmy2	—	7.5YR 4/4	LS			Gradual Wavy	Few	Vesicular	Strong
BCy	—	10YR 5/4	LS			Gradual Wavy	Very few	Vesicular	Strong
Cy1	—	10YR 6/3	SL			Gradual Wavy	Very few	Vesicular	Strong
Cy2	—	10YR 5/3	SiL			Abrupt Smooth	Very few	Vesicular	Strong
R	40+	—	—	—	—	—	—	—	—

Physical and Chemical Analyses

Horizon	Depth (cm)	Stones		Sand %	Silt %	Clay %	pH	Org. C %	N %	C:N Ratio	Exchange Analysis (meq/100 g)					
		Dominant Size (cm)	%								Ca	Mg	K	Na	H	CEC
Ah	—	0.2-0.5 1.5+	6	87	10	3	3.9	4.7	0.2	23	1.2	0.4	0.2	0.1	13.7	18.1
Bmy1	—	0.2-0.5 3+	21	85	11	4	4.3	0.8	Tr	—	0.1	0.1	Tr	Tr	4.9	5.1
Bmy2	—	0.2-0.5 2.5+	14	82	17	1	5.0	0.3	Tr	—	0.2	Tr	Tr	Tr	2.8	2.7
BCy	—	0.2-0.5 3+	19	78	20	2	5.0	0.1	—	—	0.1	Tr	Tr	Tr	2.1	2.1
Cy1	—	0.2-0.5	7	64	35	1	4.8	—	—	—	0.1	Tr	Tr	Tr	2.3	2.1
Cy2	—	0.5-1	0.5	40	57	3	5.0	—	—	—	0.2	Tr	Tr	Tr	2.5	2.5

Tr: less than 0.1

All soil associates of this association are affected by cryoturbation (indicated by disrupted soil horizons and intrusions of soil materials into other horizons). Although Cryosolic soils occur in all drainage positions, the majority of the soils on well-drained sites are Brunisols. Soils in this association have a moderately well-developed Bmy or Bgy horizon. Cryosolic associates have the permafrost table within the control section and their perennially frozen horizons are associated with segregated ice crystals, vein ice, and ice lenses. Most of the cryoturbated Brunisols and Turbic Cryosols, especially those associated with patterned ground, have thixotropic properties. In these soils, liquification takes place due to mechanical disturbance.

The topography is rolling, with low hills and valleys, and the terrain is spotted with numerous lakes and ponds. The associated patterned ground types are nonsorted circles and nonsorted steps. The vegetation is Heath-Lichen or Shrub-Heath on well-to-imperfectly drained areas and Sedge Meadow on poorly drained locations. Patches of stunted spruce may occur on slopes and along drainages.

Soil characteristics of an Eluviated Dystric Brunisol, cryoturbic phase, are given in Table 11.

COLDBLOW LAKE 2 ASSOCIATION (Map Symbol Co2)

Characteristic shallow till soils in ecodistrict HS_{ST}¹.

Coldblow Lake 2 association consists of well-drained Eluviated Dystric Brunisol, cryoturbic phase, Orthic Dystric Brunisol, cryoturbic phase, imperfectly drained Gleyed Dystric Brunisol, cryoturbic phase, and poorly drained Gleysolic Turbic Cryosol, peaty phase. These soils have developed on shallow (less than 1 m), stony, noncalcareous glacial till. The texture of this glacial till, which is derived mainly from reddish Dubawnt sandstone, is sandy loam to sand.

Although all soils of this association are affected by cryoturbation (indicated by disrupted soil horizons and intrusions of soil materials into other horizons), only the poorly drained associate is Cryosol. Most of the cryoturbated Brunisols and Turbic Cryosols, especially those associated with patterned ground, have thixotropic properties. In these soils liquification takes place due to mechanical disturbance.

The topography is rolling to hilly with

numerous bedrock outcrops. Lakes and ponds are common. The associated patterned ground types are nonsorted circles and nonsorted steps. The vegetation associated with these soils is Heath-Lichen or Shrub-Heath on well-to-imperfectly drained areas and Sedge Meadow on poorly drained locations. Patches of stunted black spruce may occur on slopes and along drainages.

HOARFROST RIVER 1 ASSOCIATION (Map Symbol Hol)

Characteristic soils of glaciofluvial and fluvial materials in all High Subarctic ecodistricts (HS_{ST}¹, HS_{ST}², HS_{ST}³, HS_{ST}⁴, HS_{FT}⁵, and HS_{FT}⁶).

Hoarfrost River 1 association consists of well-drained Eluviated Dystric Brunisol and Orthic Dystric Brunisol, imperfectly drained Gleyed Dystric Brunisol, and poorly drained Gleysolic Turbic Cryosol, peaty phase. These soils have developed on deep, noncalcareous, sand and gravel ice-contact and fluvial materials.

All of these soils have well-developed Bm or Bg horizons. The poorly drained associates have the permafrost table within the control section and their perennially frozen horizons are associated with segregated ice crystals.

This soil association occurs on eskers and outwash materials associated with eskers; thus, the topography is ridged or gently undulating. The most common vegetation found on these sandy materials is lichen and low shrubs (mainly ericaceous types) with patchy or very open spruce cover.

SLED LAKE 1 ASSOCIATION (Map Symbol S11)

Characteristic peatland soils of all High Subarctic ecodistricts (HS_{ST}¹, HS_{ST}², HS_{ST}³, HS_{ST}⁴, HS_{FT}⁵, and HS_{FT}⁶).

Sled Lake 1 association consists of Fibric Organic Cryosol and Mesic Organic Cryosol soils developed on deep peat materials. The peat material is moderately (mesic) to weakly (fibric) decomposed fen peat. These soils are associated with polygonal peat plateaus and high-center lowland polygons. All of these soils contain large amounts of ice in the form of ice wedges, ice lenses, and ice crystals.

The vegetation associated with this soil association is lichens, mosses, dwarf birch, and ericaceous shrubs. Soil characteristics of a Mesic Organic Cryosol are given in Table 12.

Table 11: Coldblow Lake 1 association: morphological description and physical and chemical analyses of an Eluviated Dystric Brunisol, cryoturbic phase (P43)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Ah	0- 5	10YR 3/2	LS			Clear Broken	Plentiful	—	None
Ahey	—	10YR 7/2	LS	Structureless Single grain	Nonsticky Nonplastic	Clear Broken	Few	—	Medium
Bmy1	—	7.5YR 5/4	SL			Clear Broken	Very few	Vesicular	Strong
Bmy2	14-25	7.5YR 6/4	SL			Gradual Smooth	Very few	Vesicular	Strong
BCy	25-40	7.5YR 6/4	SL			Gradual Smooth	Very few	—	Strong
Cy	40-60	7.5YR 8/6	SL				—	—	Strong

Physical and Chemical Analyses

Horizon	Depth (cm)	Stones		Sand %	Silt %	Clay %	pH	Org. C %	N %	C:N Ratio	Exchange Analysis (meq/100 g)					
		Dominant Size (cm)	%								Ca	Mg	K	Na	H	CEC
Ah	0- 5	0.2-0.5	10	78	17	5	3.9	1.0	0.2	5.0	1.6	1.0	0.2	Tr	8.0	10.8
Ahey	—	0.5-1	10	76	21	3	4.0	0.7	0.1	7.0	0.2	0.2	0.1	Tr	4.7	5.2
Bmy1	—	0.2-1	20	59	36	5	4.4	0.4	Tr	—	0.1	0.1	Tr	Tr	3.2	3.4
Bmy2	14-25	0.5-1	2	61	36	3	4.6	0.1	—	—	0.2	0.1	Tr	Tr	2.0	2.3
BCy	25-40	0.5-1	7	67	30	3	5.0	0.1	Tr	—	0.2	0.2	Tr	Tr	0.9	1.3
Cy	40-60	0.5-1 2+	20	57	38	5	5.9	Tr	—	—	0.4	0.3	Tr	Tr	0.8	1.5

Tr: less than 0.1

Table 12: Sled Lake 1 association: morphological description and physical and chemical analyses of a Mesic Organic Cryosol (DP4)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Om	0- 34	5YR 2.5/2	Mesic	—	Loose	Abrupt	Few	—	None
Omz	34- 84	10YR 2/1	Mesic	—	Hard, frozen	Clear	None	—	None
Ohz	84-126	10YR 2/2	Humic	—	Hard, frozen	Abrupt	None	—	None
IICz	126+	—	SL	—	—	—	None	—	—

Physical and Chemical Analyses

Horizon	Depth (cm)	Fiber Content %		Ash %	Pyrophos. %	pH	Org. C %	N %	C:N ratio	Exchange Analysis (meq/100 g)					
		Rubbed	Unrubbed							Ca	Mg	K	Na	H	CEC
Om	0- 34	36	60	13.8	21.7	4.0	58.3	2.1	28	20.5	2.2	0.1	0.1	81.3	104
Omz	34- 84	32	48	8.4	31.2	4.3	58.9	1.5	39	32.8	8.0	0.3	0.1	95.8	137
Ohz	84-126	—	—	19.6	44.6	4.9	54.1	1.7	32	38.4	13.9	0.3	0.1	77.2	130
IICz	126+	—	—	—	—	—	—	—	—	—	—	—	—	—	—

PORTER LAKE 1 ASSOCIATION (Map Symbol Pol)

Characteristic till soils of the Low Subarctic ecodistricts (LS1, LS2, LS3, and LS4).

Porter Lake 1 association consists of well-drained Eluviated Dystric Brunisol, imperfectly drained Gleyed Brunisol, and poorly drained Rego Gleysol, peaty phase. These soils have developed on deep, stony, noncalcareous glacial till which is derived mainly from granitic rocks. The texture of this glacial till is sandy loam to loamy sand (Table 4).

The Eluviated Dystric Brunisol has well-developed Bm and Ae horizons. The Rego Gleysol, peaty phase, is associated with varying amounts of surface peat.

The topography is rolling with low hills and

valleys and the terrain is spotted with numerous lakes and ponds. The vegetation is an open coniferous woodland with a well-developed carpet of lichens on well-to-imperfectly drained areas, and black spruce-moss vegetation on poorly drained locations.

Soil characteristics of an Eluviated Dystric Brunisol are given in Table 13.

PORTER LAKE 2 ASSOCIATION (Map Symbol Po2)

Characteristic shallow till soils of the Low Subarctic ecodistricts (LS1, LS2, LS3, and LS4).

The soils of this association and their parent materials are very similar to those of the Porter Lake 1 association. The parent material, however, is shallow (less than 1 m). Due to the shallowness of the soil,

Table 13: Porter Lake 1 association: morphological description and physical and chemical analyses of an Eluviated Dystric Brunisol (P4)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Ah	0- 1	—	LS			Clear Broken	Few	—	—
Ae	1- 3	10YR 8/1	LS	Structureless Single grain	Nonsticky Nonplastic	Abrupt Smooth	Few	—	—
Bm	3-15	10YR 5/6	LS			Gradual Wavy	Few	—	—
BC	15-25	2.5YR 7/4	LS			Gradual Wavy	Few	—	—
C	25+	10YR 7/3	LS			—	None	—	—

Physical and Chemical Analyses

Horizon	Depth (cm)	Stones		Sand %	Silt %	Clay %	pH	Org. C %	N %	C:N Ratio	Exchange Analysis (meq/100 g)					
		Dominant Size (cm)	%								Ca	Mg	K	Na	H	CEC
Ah	0- 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ae	1- 3	0.2-0.5 2+	26	82	16	2	3.8	1.0	Tr	—	0.2	0.1	Tr	Tr	4.7	5.0
Bm	3-15	0.5-1 3+	47	72	26	2	5.2	0.5	Tr	—	0.1	0.1	Tr	Tr	4.0	4.2
BC	15-25	0.2-0.5 3+	26	84	15	1	5.4	0.5	—	—	0.3	0.2	Tr	0.1	1.3	1.9
C	25+	0.5-1 3.5+	30	85	14	1	5.5	—	—	—	0.1	Tr	Tr	Tr	0.4	0.5

Tr: less than 0.1

bedrock outcrops are very frequently found in such areas. The vegetation associated with these soils is usually an open coniferous woodland with a well-developed carpet of lichens, though there are occasional closed-crown moss-forest patches.

ODIN LAKE 1 ASSOCIATION (Map Symbol Od1)

Characteristic soils of glaciofluvial and fluvial materials in all Low Subarctic ecodistricts (LS1, LS2, LS3, and LS4).

Odin Lake 1 association consists of well-drained Eluviated Dystric Brunisol, imperfectly drained Gleyed Dystric Brunisol, and poorly drained Rego Gleysol, peaty phase. These soils have developed on deep, noncalcareous, sand and gravel ice-contact and fluvial materials. The Eluviated Dystric Brunisol has a well-developed Bm or Bfj horizon which is very often associated with a weakly cemented layer.

This soil association occurs on eskers and outwash materials, and the topography is ridged or gently undulating. Much of the vegetation is an open coniferous forest with a well-developed carpet of lichens.

Soil characteristics of an Eluviated Dystric Brunisol are given in Table 14.

DYMOND LAKE 1 ASSOCIATION (Map Symbol Dyl)

Characteristic peatland soils of all Low Subarctic ecodistricts (LS1, LS2, LS3, and LS4).

Dymond Lake 1 association consists of Fibric Organic Cryosol and Mesic Organic Cryosol soils, developed on deep peat materials. The peat materials are undecomposed (fibric) Sphagnum peat with peat plateaus, polygonal peat plateaus, and palsas, and all contain large amounts of ice in the form of ice crystals, ice lenses, and ice wedges.

The vegetation associated with these soils is either an open black spruce woodland on peat plateaus or a community of lichens and ericaceous shrubs on polygonal peat plateaus. Soil characteristics of a Fibric Organic Cryosol are shown in Table 15.

NONACHO LAKE 1 ASSOCIATION (Map Symbol Nal)

Soils in ecodistrict HB1.

Nonacho Lake 1 association consists of well-drained Eluviated Dystric Brunisol, imperfectly drained Gleyed Dystric Brunisol, and poorly drained Rego Gleysol, peaty phase.

These soils have developed on deep, stony, noncalcareous glacial till which is derived mainly from granitic rocks. The texture of this glacial till is sandy loam to loamy sand.

The Eluviated Dystric Brunisol has well-developed Bm and Ae horizons. The Rego Gleysol, peaty phase, is associated with varying amounts of surface peat.

The topography is rolling with low hills and valleys and the terrain is spotted with numerous lakes and ponds. The vegetation is black spruce-jack pine forest on well-to-imperfectly drained areas, and black spruce-moss vegetation on poorly drained locations.

NONACHO LAKE 2 ASSOCIATION (Map Symbol Na2)

Characteristic shallow till soils of High Boreal ecodistricts (HB1 and HB2) and Mid Boreal ecodistricts (MB1 and MB2).

Nonacho Lake 2 association consists of well-drained Eluviated Dystric Brunisol, lithic phase, imperfectly drained Gleyed Dystric Brunisol, lithic phase, and poorly drained Rego Gleysol, peaty phase. These soils have developed on shallow (less than 1 m), stony, noncalcareous glacial till which is derived mainly from granitic rocks. The texture of this glacial till is sandy loam to loamy sand.

Due to the shallowness of the soil, bedrock outcrops are frequently found in this area. The vegetation is black spruce-jack pine forest on well-to-imperfectly drained areas, and black spruce-moss vegetation on poorly drained locations.

SNOWDRIFT RIVER 1 ASSOCIATION (Map Symbol Snl)

Characteristic soils of glaciofluvial and fluvial materials in High Boreal ecodistricts (HB1 and HB2).

Snowdrift River 1 association consists of well-drained Eluviated Dystric Brunisol, imperfectly drained Gleyed Dystric Brunisol, and poorly drained Rego Gleysol, peaty phase. These soils have developed on deep, noncalcareous, sand and gravel ice-contact and fluvial materials. The Eluviated Dystric Brunisol has a well-developed Bm or Bfj horizon which is very often associated with a weakly cemented layer.

This association occurs on eskers and outwash materials, and the topography is ridged or gently undulating. Much of the vegetation is

Table 14: Odin Lake 1 association: morphological description and physical and chemical analyses of an Eluviated Dystric Brunisol (P2)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Ah	0- 8	7.5YR 2/0	S	Structureless Single grain	Nonsticky Nonplastic	Clear Wavy	Plentiful	—	None
Ae	8- 20	10YR 7/2	S			Abrupt Wavy	Few	—	None
Bm	20- 37	10YR 6/8	S			Gradual Wavy	Plentiful	—	None
BC	37- 69	10YR 6/4	S			Gradual Wavy	Few	—	None
C	69-100	10YR 7/3	S			—	None	—	None

Physical and Chemical Analyses

Horizon	Depth (cm)	Stones		Sand %	Silt %	Clay %	pH	Org. C %	N %	C:N Ratio	Exchange Analysis (meq/100 g)					
		Dominant Size (cm)	%								Ca	Mg	K	Na	H	CEC
Ah	0- 8	—	—	92	5	3	3.2	6.7	0.2	38	1.1	0.1	0.2	Tr	11.8	13.2
Ae	8- 20	—	—	90	9	1	3.9	0.2	Tr	—	Tr	Tr	Tr	Tr	2.1	2.1
Bm	20- 37	0.5	5	93	6	1	5.1	0.4	Tr	—	Tr	Tr	Tr	Tr	3.6	3.6
BC	37- 69	—	—	97	3	—	4.8	0.1	—	—	Tr	Tr	Tr	Tr	1.1	1.1
C	69-100	0.2-0.5	1	99	1	—	4.9	—	—	—	0.1	Tr	Tr	Tr	0.2	0.3

Tr: less than 0.1

Table 15: Dymond Lake 1 association: morphological description and physical and chemical analyses of a Fibric Organic Cryosol (P5)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Of	0- 36	2.5YR 3/4	Fibric	—	Loose	Abrupt	Few	—	—
Of1	36- 54	7.5YR 4/4	Fibric	—	Hard, frozen	Gradual	None	—	—
Of2	54-116	2.5YR 2.5/2	Fibric	—	Hard, frozen	—	None	—	—

Physical and Chemical Analyses

Horizon	Depth (cm)	Fiber Content %		Ash %	Pyrophos. %	pH	Org. C %	N %	C:N ratio	Exchange Analysis (meq/100 g)					
		Rubbed	Unrubbed							Ca	Mg	K	Na	H	CEC
Of	0- 36	80	96	1.9	9.3	3.0	57.7	0.5	115	17.5	5.5	0.3	0.2	127.1	151
Of1	36- 54	96	100	1.7	6.0	3.1	57.6	0.4	144	21.5	5.2	0.1	0.3	124.0	151
Of2	54-116	54	76	5.9	29.2	3.4	60.7	1.7	36	22.0	4.3	0.2	0.2	128.2	155

an open coniferous woodland with a well-developed carpet of lichens.

REDCLIFF ISLAND 1 ASSOCIATION (Map Symbol Rel)

Characteristic soils of fine lacustrine materials in Mid Boreal ecodistrict MBI.

Redcliff Island 1 association consists of well-to-imperfectly drained Orthic Turbic Cryosol and poorly drained Gleysolic Turbic Cryosol. These soils have developed on noncalcareous clay loam to clay-textured lacustrine sediments.

These soils are affected by cryoturbation as manifested by disrupted and dislocated soil horizons, intrusions of soil materials from other horizons, and hummocky microtopography. The perennially frozen soil materials contain medium-to-high amounts of ground ice.

The topography is level to undulating and the associated patterned ground type is earth hummocks. The vegetation on these soils is

black spruce, Ledum, and mosses. The hummock tops, which are generally devoid of trees, are dominated by lichens.

Soil characteristics of an Orthic Turbic Cryosol are given in Table 16.

TALTSON RIVER 1 ASSOCIATION (Map Symbol Tal)

Characteristic peat soils of High Boreal ecodistricts (HBI and HB2).

Taltson River 1 association consists of Mesic Organic Cryosol and Fibric Organic Cryosol soils developed on deep peat materials. The peat materials are undecomposed (fibric) Sphagnum peat and moderately decomposed (mesic) fen peat. These soils are associated with peat plateaus and palsas. All of these soils contain high amounts of ice in the form of ice crystals and ice lenses.

The vegetation associated with this soil association is a closed or open black spruce forest.

Table 16: Redcliff Island 1 association: morphological description and physical and chemical analyses of an Orthic Turbic Cryosol (P12)

Morphological Description

Horizon	Depth (cm)	Color (moist)	Texture	Structure	Consistence	Horizon Boundary	Root Description	Pore Description	Cryoturbation
Aey	0- 5	10YR 7/4	SiL	Weak, Platy	Slightly sticky, Slightly plastic	Clear Broken	Few	—	Medium
Bmy	0-40	7.5YR 4/2	C	Moderate Granular	Sticky Plastic	Gradual Irregular	Plentiful	—	Medium
BCy	40-50	7.5YR 5/2	C	Structureless Massive	Sticky Plastic	Gradual Wavy	Few	—	Medium
C	50-80	7.5YR 5/2	C	Structureless Massive	Sticky Plastic	Abrupt Wavy	None	—	None
Cz	80+	—	C	Frozen Massive	—	—	None	—	None

Physical and Chemical Analyses

Horizon	Depth (cm)	Stones		Sand %	Silt %	Clay %	pH	Org. C %	N %	C:N Ratio	Exchange Analysis (meq/100 g)					
		Dominant Size (cm)	%								Ca	Mg	K	Na	H	CEC
Aey	0- 5	—	0	20	58	22	5.2	1.1	Tr	—	4.6	2.6	0.2	0.1	4.5	10.5
Bmy	0-40	—	0	2	29	69	5.9	0.8	0.1	8	8.4	7.9	0.6	0.1	4.8	20.0
BCy	40-50	—	0	1	20	79	6.2	0.8	0.1	8	10.1	9.3	0.7	0.2	4.3	22.6
C	50-80	—	0	1	19	80	6.6	—	—	—	9.0	7.9	0.7	0.3	4.2	19.4
Cz	80+	—	0	—	—	—	—	—	—	—	—	—	—	—	—	—

Tr: less than 0.1

FORT SMITH 1 ASSOCIATION (Map Symbol Fol)

Characteristic soil of medium-textured lacustrine materials in Mid Boreal ecodistrict MB2.

Fort Smith 1 association consists of well-drained Orthic Eutric Brunisol and Eluviated Eutric Brunisol, and poorly drained Rego Gleysol, peaty phase. These soils have developed on deep, weakly calcareous sand to loam-textured lacustrine and deltaic materials.

The well-drained associates (Orthic Eutric Brunisol and Eluviated Eutric Brunisol) of this association have developed mainly on the sandy materials. They have a thin mat of organic material (L-H) and a brownish Bm horizon. The eluviated Eutric Brunisol soils have a well-developed, leached Ae horizon underlain by a brown Bm horizon. The loam-textured materials occupy troughs between low ridges of sandier materials. The soils associated with these loamy materials are Rego Gleysols, peaty phase.

The topography is level to gently undulating and narrow-ridged dunes are present in some places. The vegetation on well-drained sites is a closed forest of trembling aspen, jack pine, and white spruce. The poorly drained areas are dominated by dwarf birch, willows, and, in some places, black spruce and tamarack.

A description of these soils, along with chemical and physical analyses, is found in the report by Day (1972).

NORBERTA 1 ASSOCIATION (Map Symbol Nol)

Characteristic soils of alluvium in Mid Boreal ecodistrict MB2.

Norberta 1 association consists dominantly of poorly drained Rego Gleysol, peaty phase, and some well-drained Orthic Regosol and Cumulic Regosol.

The Rego Gleysol, peaty phase associate has a peaty layer of varying thickness (10-20 cm). This peaty layer is composed mainly of sedge peat materials. On well-drained positions, little or no soil development has taken place on these recent alluvial materials, and the associated soils are Regosols.

The topography is level to depressional. The vegetation is dominantly dwarf birch, willows, and tamarack on poorly drained positions, while the well-drained areas are

covered with trembling aspen and white spruce.

A description of these soils, together with the chemical and physical analysis, is found in the report by Day (1972).

4. PERMAFROST

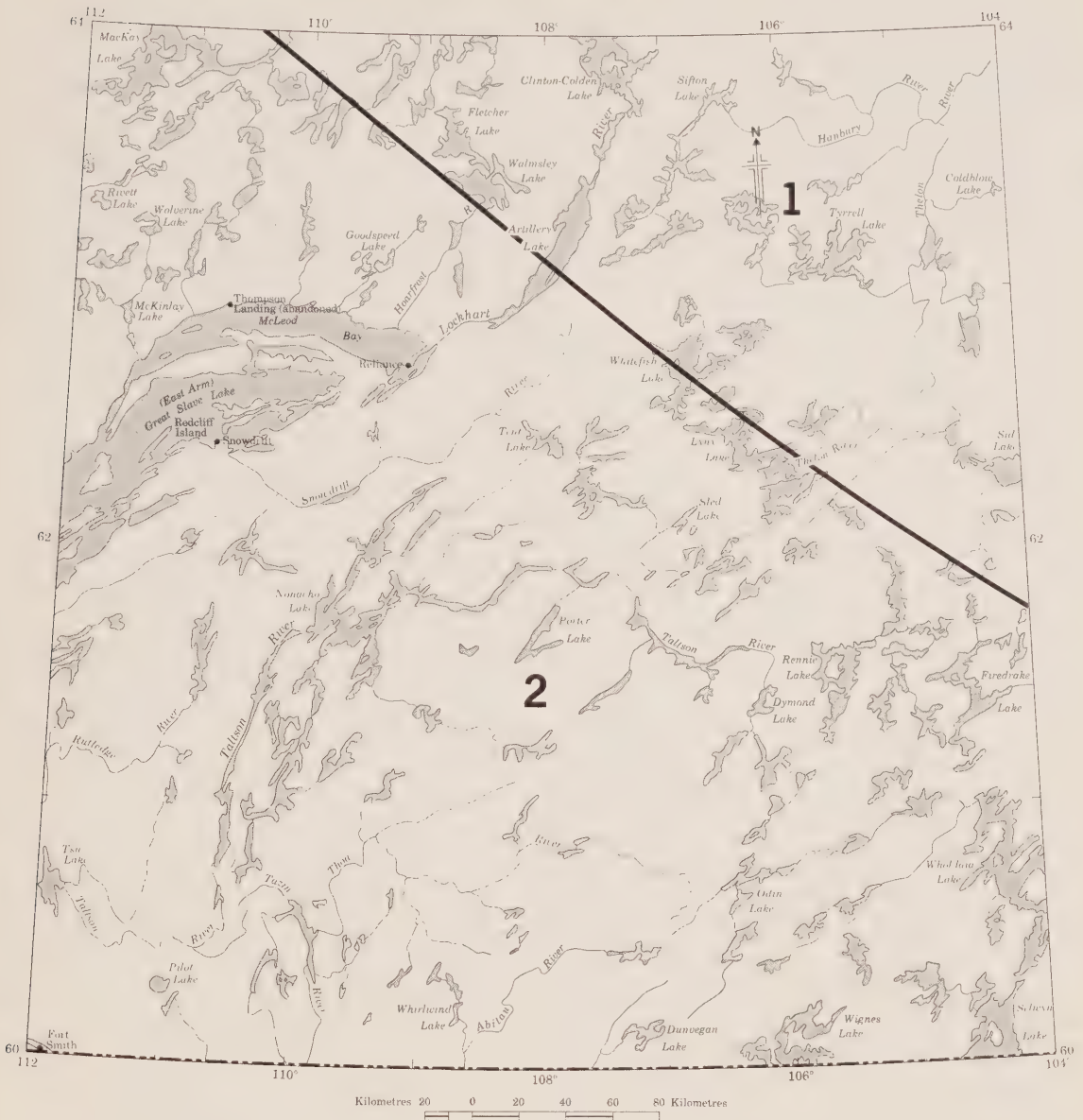
Most of the LRMA lies within the Widespread Discontinuous Permafrost Zone of Brown (1967), and only the northeastern part of the map sheet is in the zone of Continuous Permafrost (Figure 16).

In the Widespread Discontinuous Zone there is much permafrost beneath the land surface, but it is not continuous. Permafrost bodies in well-drained mineral terrain, if present, lie deep below the surface; hence, the active layer is generally deep. On peatlands, the thickness of the active layer is 30-50 cm in the southern part and 30-40 cm in the northern part of the zone. Patterned ground features are found mainly in the form of peat plateaus and some polygonal peat plateaus in the southern part, with nonsorted circles, nonsorted steps, and polygonal peat plateaus in the northern part.

In the Continuous Zone, permafrost exists everywhere beneath the land surface. The thickness of the active layer on till materials in the Lynx Lake area, near the southern limit of the Continuous Permafrost boundary, was found to be greater than 2 m on well-drained till and approximately 35 cm on poorly drained till with thin surface peat (Figure 15). On perennially frozen peatlands, the active layer is about 30-35 cm thick (Figure 15). Patterned ground features associated with this zone are nonsorted circles, nonsorted steps, ice-wedge polygons on mineral terrain, and polygonal peat plateaus plus some high-center lowland polygons on organic terrain.

No data are available for the thickness of the permafrost within the LRMA. Information is available, however, for some adjacent areas. At Yellowknife, westward on the north shore of Great Slave Lake, the thickness of permafrost was found to range from 61 to 91 m, while in Uranium City, Saskatchewan, just south of the map area, it was found to be 9 m. Both locations are in the Widespread Discontinuous Zone. At Tundra Gold Mines Ltd., 240 km northeast of Yellowknife near the southern limit of the Continuous Zone, the permafrost was reported to be 274 m thick (Brown, 1970).

Figure 16: Distribution of permafrost in the Caribou Range map area (Brown, 1967).
See also Figure 2.



— SOUTHERN LIMIT OF CONTINUOUS PERMAFROST

1

CONTINUOUS PERMAFROST

2

WIDESPREAD DISCONTINUOUS PERMAFROST

SECTION M
VEGETATION

VEGETATION

1. INTRODUCTION

Vegetation is only one component of landscape ecosystems, but special importance is attached to it as the productivity base. It fixes the carbon, builds up organic matter, provides food and shelter for animals, stabilizes soils, and influences hydrologic regime. Ecological land classification is based on known and observed relationships between vegetation and landforms, reflecting spatial gradients in climatic energy-moisture processes at all scales.

In studying the spatial assemblages of plants that comprise 'vegetation', description and classification usually rely on the characteristics of structure (physiognomy), composition (floristics), function (ecological relationships), and development (genesis, the time relationships). At the regional level, where major vegetational divisions or 'formations' match zonal and subzonal landscapes, the structural-functional approach is most useful. At lower levels, from the subregional to the local, increasing use can be made of composition and of development (successional status). There is another possibility that has not often been exploited, namely, to utilize the spatial relationships of communities to class them in functional ways (e.g., by presenting them as topographic catenas or 'associations' in the pedologist's sense).

In this section, the major zonation of vegetation in the LRMA is first established to provide a framework for subsequent discussions of the history of the vegetation and of local types in their catenary relationships.

2. REGIONAL VEGETATION

The literature concerning vegetation zones and regions in the northern hemisphere is large and confusing. The trouble is partly semantic; the meaning of such terms as 'taiga' and 'boreal' has been blurred by the different usages of geographers, climatologists, and phytosociologists. Nevertheless, there is international recognition of several circumpolar biogeoclimatic zones south of the Arctic (e.g., Sjörs, 1963; Ahti *et al.*, 1968; Hare and Ritchie, 1972):

- A) Forest Tundra transition ('Hémiarctique' of Rousseau, 1952; 'Sylvotundra' of Maini, 1966; 'Woodland Tundra' of Andreyev per Alexandrova, 1970).
- B) Northern Boreal Open Woodland ('Boreal

Woodland Subzone' or 'Open Coniferous Forest' of Hare and Ritchie, 1972; 'Subarctic Woodland' of Rowe, 1972; 'Lichen Woodland' of Kershaw, 1977).

- C) Main or Middle Boreal Closed-Crown Forest ('Boreal Forest Subzone' or 'Closed Coniferous Forest' of Hare and Ritchie, 1972).

Problems arise with use of the term 'Subarctic' defined by both Hustich (1966) and Löve (1970) as equivalent to the 'Hemiarctic'; i.e., the Forest Tundra transition between the Open Lichen Woodland (Northern Boreal above) and the treeless Arctic. This idea of a unique ecotone hinges on Rousseau's (1952) phytogeographical definition of the 'Hémiarctique' as an 'emulsion' of Arctic and Northern Boreal habitats, with an Arctic flora on the topographic rises "imprisoned in a net of subarctic forest strips" in the intervening lowlands. However, in the LRMA and in similar terrain in northern Manitoba (Ritchie, 1956), the 'tundra' of the transition zone is characterized not so much by the presence of an Arctic flora as by the absence of trees. In other words, the tundra on the topographic rises is only unique physiognomically; it is composed of the same species (lichens and dwarf shrubs) that typify Open Lichen Woodland. The same has been reported by Kelsall *et al.* (1971) for the 'tundra ecotone' north of the Lockhart River to 63°05' latitude, and by Ducruc *et al.* (1976) for the James Bay area in Quebec where, in the 'Zone Hémiarctique', most species on the tundra interflaves are Boreal rather than Arctic in affinity.

The evidence favours treating Forest Tundra as a northern fringe of the Boreal and Subarctic rather than as a half-way transition to the Arctic. This makes good sense when it is realized that 'tundra' need imply no Arctic plant elements but only the absence of trees. Then the Forest Tundra is placed as part of the High Subarctic closely related to the Low Subarctic Woodlands, as shown in Table 17.

Several features of this scheme should be noted. The 'Subarctic', a term often used to describe the climate of the Boreal, is treated as a zone in its own right. Also, a Shrub Tundra subdivision of the High Subarctic is recognized which, in its northern parts, approaches the phytogeographic concept of the 'Hémiarctique' as defined by Rousseau (1952). A somewhat similar proposal has been advanced by Payette *et al.* (1975) who divided the 'Hémiarctique' of Ungava into a southern subzone where the tree form is present (our

Table 17: Major vegetation regions and subregions in the LRMA

ECOREGIONS	SUBREGIONS	VEGETATION CHARACTERISTICS	NORTHERN BOUNDARY CRITERIA
HIGH SUBARCTIC (Hemiarctic)	Shrub Tundra	Tree species present in low forms	Tree Species Limit (Polar Species Line of Hustich, 1966)
	Forest Tundra	Tree growth-form in patches	Tree-form Line (limit of the evident tree life-form, except on eskers)
LOW SUBARCTIC	N.A.	Open Lichen Woodland	Treeline; uplands treeless (50% landscape with tree cover marks Forest Line of Hare and Ritchie, 1972, and the Physiognomic Forest Line of Hustich, 1966)
HIGH BOREAL	N.A.	Closed-crown conifer forests	Forestline; limit of close-grown trees (Economic Forest Line of Hustich, 1966)
MID BOREAL	N.A.	Closed-crown deciduous-and-conifer forests	Mixedwood Forestline; limit of close-grown <i>Populus-Picea</i> stands.

Forest Tundra) and a northern shrub subzone where tree species occur but with a growth form that is scrubby and krummholz (our Shrub Tundra). This also seems to match the Russian view that a subarctic shrub and bush tundra be recognized poleward from the 'Woodland Tundra' (Tikhomirov, 1960; Alexandrova, 1970).

3. VEGETATION HISTORY

The LRMA shares a fairly recent postglacial history with the vast area from the west side of Hudson Bay to the Mackenzie Mountains and the Beaufort Sea. A general picture of Holocene events is emerging which helps to explain the character of today's landscapes.

1) Paleobotany

Maps by Prest (1974) and Bryson *et al.* (1969) indicate a west-to-east deglaciation of the

LRMA between 9000 and 6000 BP (Figure 17). This presumed chronology is supported by preliminary paleobotanical studies carried out near the center of the area in 1976-77.

Only one of three lakes sampled yielded an adequate core; 1.75 m of unconsolidated sediment was recovered from 5 m of water at the south end of a nameless lake, lying 4 km northwest of Porter Lake (61°55' latitude, 108° longitude). Two of three samples yielded enough benzene for analysis at the Radiocarbon Laboratory of Brock University. They produced ages for the lower part of the section that conform satisfactorily with the proposed time of Wisconsin ice withdrawal from the region, confirming that deglaciation took place about 7500 BP.

A summary pollen diagram (Figure 18) suggests the broad outlines of the pollen stratigraphic sequence and provides a basis

Figure 17: Ice-retreatal positions in the LRMA (after Bryson et al., 1969).
Contour numbers are in thousands of years before the present.

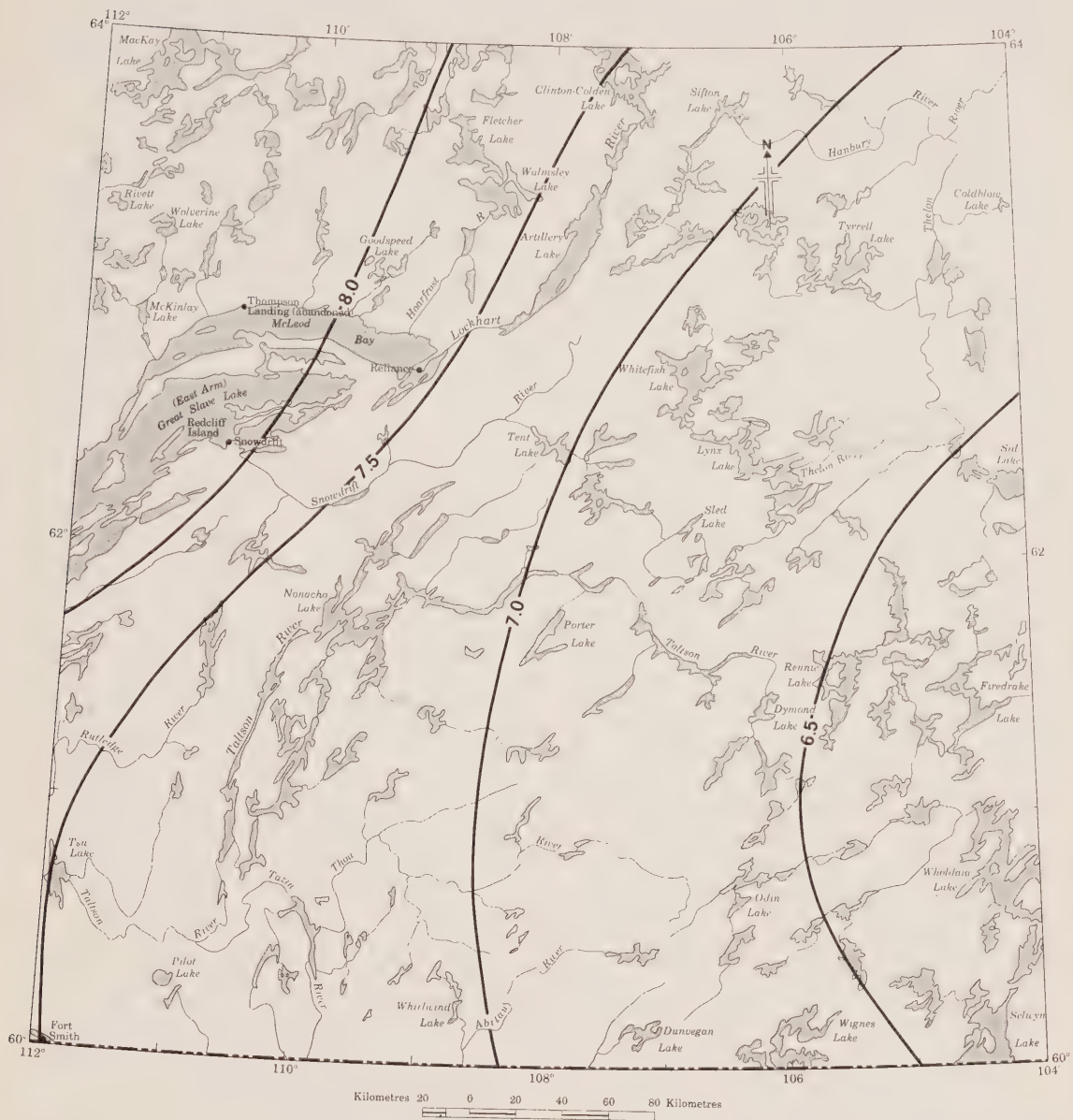


Figure 18: Summary pollen diagram, Porter Lake, N.W.T., 61°55' latitude, 108° longitude



for a preliminary reconstruction of the Holocene vegetation.

The diagram can be subdivided easily into three zones:

Zone I is dominated by pollen of the shrub birch, associated with willow, sedges, and low frequencies of *Artemisia*. Spruce frequencies were as high in this zone as at present, but neither pine nor alder was represented in frequencies high enough to suggest their presence at that time. It is likely that the vegetation was an open spruce parkland with abundant dwarf birch tundra.

Zone II shows the sharp increase of alder pollen to almost half the total for several levels. However, alder is overrepresented normally, and it is likely that the relative abundance of the shrub was not much greater than at present. Tree birch pollen becomes frequent in Zone II, and a reconstruction is suggested of a spruce-birch woodland with openings and local alder.

Zone III begins with the rise of pine pollen to modern frequencies, and signals the

migration of pine to this latitude by about 5000 BP. The upper 75 cm of the section suggests no major regional shifts in vegetation.

These results fit well with the general reconstruction that is emerging for the Lower Mackenzie Valley and adjacent uplands eastward.

2) Postglacial Climate

If the above chronology is accepted, the LRMA was deglaciated at a time when, according to current evidence, summer temperatures averaged 5-10°C warmer than today, allowing the survival of forest several hundred kilometers north of present treeline (Ritchie and Hare, 1971; Nichols, 1976; Delorme *et al.*, 1977). It follows that the entire area was under the influence of a relatively mild Boreal climate for at least several thousand years.

A significant climatic cooling began around 4000 BP according to the authorities just mentioned, and there is some evidence in Keewatin of several minor warming and cooling

episodes since then (Sorenson, 1977). Assuming forest advance into the tundra during warm periods and retreat during cold periods, then present-day plant distributions may in part be relict features, maintained 'out of place' by inertial lag in ecosystem response to recent climatic changes and by local compensatory environments.

3) Postglacial Forest Vegetation

Treeline -- the woodland border where tundra becomes prominent on the hilltops -- is assumed to be a major ecotone in the study area. It is roughly approximated by a line running northwest to southeast from Artillery Lake to Firedrake Lake. Presumably this line was displaced at least as far as the Thelon Basin during the Climatic Optimum (Hypsithermal), and perhaps that far again as late as 1200-1000 BP in the 'Little Climatic Optimum' when Scandinavian explorers, encouraged by the warming climate, attempted to colonize northern Canada (Nichols, 1970, 1976).

Patches of stunted conifers are found in sheltered drainages and by lakeshores, where snowbanks accumulate yearly, all through the northern and northeastern parts of the LRMA. These small clones of black spruce may be vegetatively reproducing survivors from 3500 years ago (Nichols, 1976). Beyond treeline, the more conspicuous tamarack and white spruce are also capable of reproducing by layering, but they rarely do so. Their presence therefore suggests at least intermittent seed production in locally favourable environments.

The Thelon Basin in the northeast corner is one such favourable locale (Clarke, 1940). Here, disjunct forests of spruce and tamarack thrive on gentle slopes and flood plains. Gordon (1975) reported white spruce 385 years old, 19 m tall, and 60 cm in diameter at breast height. He suggested that the upper Thelon River has unique qualities that counteract its northerly location: the shelter of a topographic depression and "a warm westerly summer wind". He found needles of black spruce and tamarack associated with the Arctic Small Tool Occupation artifacts dated 3500-3000 BP, additional evidence that forest had reached the Thelon prior to the climatic deterioration that terminated the Hypsithermal.

We found a number of 'southern Boreal' species at the few collecting points visited on the Thelon. One open white spruce grove, which sheltered a musk-oxen herd, had an undergrowth of Alnus crispa, beneath which

were found Linnaea borealis, Habenaria obtusata, and Lycopodium annotinum sharing ground with such Arctic species as Oxyria digyna and Salix reticulata. In short, the evidence for a compensating forest climatic regime 100-200 km beyond treeline is strong.

The conifers (spruce and tamarack) are widely distributed beyond treeline, but only in the Forest Tundra ecotone is the upright tree form well expressed on moraine. Nevertheless, the potential for forest expansion is widespread and may be realized periodically when climatic cycles shift to favour growth and seed production. Probably in the last few thousand years there have been several forest expansions from sheltered refuges to the uplands and to other environments that are now not favourable; however, whether the old stumps and logs that here and there litter the surfaces of tundra till uplands died out a few hundred or a few thousand years ago is not known.

4) Postglacial Peatlands

Two major kinds of peatland are recognized in the north: fen and bog. Sedge-willow fens border streams and lakeshores, forming a mesic type of peat under the influence of mineral-rich water. Sphagnum-heath bogs are higher and drier than the fens, which they often overgrow. Cut off from the minerotrophic ground water, they form an acid (less than pH4) fibric peat, which in the N.W.T. is usually perennially frozen. Thus, bogs are commonly permafrost landforms -- palsas and peat plateaus -- associated with wet unfrozen fens. They rise one to several meters above neighboring water surfaces, elevated by growth of Sphagnum plus the internal segregation of ice veins and lenses.

Various characteristics of organic terrain provide clues to present and past climates. Sphagnum grows best in the Boreal forest; therefore, thick accumulations of peat suggest bog formation in a Boreal climate. Permafrost peat plateaus are the typical sub-arctic bog variant, their surfaces forested with black spruce (near the south and west Boreal ecotone) or treeless and polygonally patterned by frost fissures (approaching Forest Tundra to the north and east). Thermokarst collapse features are a normal characteristic of peat plateaus, but accelerated melting may reflect climatic warming in the last 200 years (Thie, 1974). At and beyond treeline, shallow peat (less than 1 m in depth) is the rule. Thicker 'residual' peats are polygonally patterned by regular ice-wedge fissures. Such high-centered peat polygons are characteristic of lowlands in

the Forest Tundra transition.

The spatial sequence from relatively warm to relatively cool is unfrozen deep bogs to wooded peat plateaus to polygonal peat plateaus to eroded polygonal peat plateaus to lowland high-center polygons (thin peat).

Therefore the thickness and structure of peat at any place provides clues to past climatic sequences. Thick accumulations of peat are today found in the Subarctic; they probably formed 8000-4000 BP during the Hypsithermal, when the Boreal forest climate was displaced north-eastward. Kay (1976) has attempted to correlate peat accumulation with climatic cooling in Keewatin, but the assumed relationship seems unlikely in view of the sequence of permafrost peatland development outlined by Zoltai and Tarnocai (1975).

Because elevation of organic terrain by ice-lensing improves drainage and leads to a drying of its surface, the formation of palsas and peat plateaus usually results in a marked reduction, or even a termination, of peat formation. Therefore thick frozen peatlands, such as the polygonally patterned peat plateaus that border many subarctic lakes, indicate an earlier relatively warm climate (period of peat accumulation) followed by a relatively cold climate (period of freezing, ice segregation, elevation). The surface vegetation change from dominance by *Sphagnum* to dominance by lichens ('lichen peat plateaus') may also over the shorter term reflect the influence of fire as well as of cool-climate uplift (Rowe *et al.*, 1975).

The thinner frozen peatlands of the Forest Tundra transition may also have formed during the Hypsithermal, at the northern border of the Boreal. In their present near-tundra environment, they appear to be inactive so far as peat accumulation is concerned. Indeed, many are bare of vegetation and eroding, a result of ice-wedge recession that has left the polygonal tops high and dry. The melting may be relatively recent (in the last few hundred years) because the erosional process does not seem to have gone far in some places. Zoltai (personal communication) has surface carbon-14 dates for eroding polygonal peat plateaus that place their period of aggradation before the climatic deterioration that ended the Hypsithermal. Beyond treeline, polygonal peat plateaus appear to merge with high-center polygons, and no low-center polygons were observed in the LRMA.

The preceding historical account emphasizes the likelihood that a number of vegetational features of the landscape are inherited from

the past. It follows that the presence or absence of trees and other species, and the thickness and structure of peats, may have limited relevance for interpreting ecological processes of the present and recent past. On the other hand, the surface expressions of tree form and of permafrost have a short response time and are therefore significant to the functional understanding of today's northern landscapes.

4. LOCAL VEGETATION

The types of vegetation described by investigators at the local level reflect their purposes, interests, and especially what they readily perceive. Thus, close-grown forests are often classified by tree cover, open forests by their ground vegetation, and tundra communities by their habitats and life-form groups.

Descriptive schemes that have been used within the High Boreal, Low Subarctic, and High Subarctic have much in common. The reason is that a physiognomic approach suggests itself to all, because of the close match between topographic gradients (catenas) and communities dominated by one or two plant growth forms. Table 18 lists 15 frequently used descriptive terms (terrain and life-form groups) in their usual moisture-gradient sequences, and gives short definitions of each.

About 25 combinations of the physiognomic terms provided a simple, understandable ecological typology with wide application for description and for mapping. The types are shown in Table 19 in dry-to-wet series for the major subdivisions of the LRMA. Certain types are common throughout, others are geographically unique. Their meanings and relationships are examined next, with reference to studies by others in similar terrain.

Vegetation Types and their Common Plants
(bracketed species are less prominent;
HS=High Subarctic; B=Boreal)

Rock Lichen; Rock Lichen Woodland
(similar except for the trees *Picea mariana* and *Pinus banksiana* in the latter)

Cladonia mitis
C. rangiferina
Actinogyra mühlenbergii
Parmelia centrifuga
Parmeliopsis hyperopta
Peltigera aphthosa
P. polydactyla
Rhizocarpon geographicum

Table 18: Descriptive terms for physiognomic types of northern vegetation

Kinds of Terrain

D r y ↓ W e t	Rock	– Outcropping bedrock; a thin stony veneer may be present.
	Bog	– A form of consolidated peatland, usually dominated by <i>Sphagnum</i> species; can be deep residual peat, or shallow and “turfy”.
	Fen	– Semi-consolidated wet peatland under the influence of groundwater, usually in drainage tracks through mineral soil or bog.
	Meadow	– Wetland with a mucky substratum rather than a peat substratum as in “fen”.
	Marsh	– Perennial wetland characterized by coarse emergent aquatic plants such as bur reed and large sedges.

Forest and Shrublands

D r y ↓ W e t	Woodland	– Open areas with trees widely spaced so that the forest floor is exposed to sun and skylight; trees can be moderately tall.
	Forest	– Trees close together so that the crowns form an almost continuous shading canopy.
	Shrub	– Broadleaved deciduous medium-to-tall shrubs (<i>Betula</i> , <i>Salix</i> , and <i>Alnus</i>).
	Shrub Thicket	– Riparian shrubland bordering water bodies and stream channels.

Low Vegetation

D r y ↓ W e t	Lichen	– Lichen communities of exposed uplands and lowlands, from outcrop and drift ridges to open and wooded peatlands.
	Grass	– Meaning “grass-like” and including not only true grass species (<i>Poa</i> , etc.), but also upland species of sedges (<i>Carex</i>) and wood-rushes (<i>Luzula</i>).
	Herb	– Meaning all non-woody (non-shrub) flowering plants, including grasses and sedges; an inclusive term compared to “Grass” above.
	Heath	– Dwarf ericoids, mostly small-leaved and evergreen or coriaceous, such as <i>Ledum</i> , <i>Empetrum</i> , <i>Arctostaphylos</i> , <i>Vaccinium</i> , <i>Loiseleuria</i> , etc.
	Moss	– Meaning primarily feather mosses and those preferring the moist or shaded habitat, such as <i>Pleurozium</i> , <i>Hylocomium</i> , <i>Dicranum</i> , <i>Polytrichum</i> , and <i>Aulacomnium</i> ; occasionally <i>Sphagnum</i> cushions may be present.
	Sedge	– Water-loving grass-like species, chiefly <i>Carex</i> , <i>Eriophorum</i> , and <i>Scirpus</i> .

Table 19: Structural vegetation types in the LRMA

	High Subarctic		Low Subarctic	High Boreal	
	Shrub Tundra	Forest Tundra		Shield Uplands	Slave Lowlands
DRY, EXPOSED	Rock Lichen Lichen-Grass	Rock Lichen	Rock Lichen Rock Lichen Woodland	Rock Lichen Rock Lichen Woodland	Rock Lichen Rock Lichen Woodland
	Heath-Lichen-Grass		Lichen Woodland	Lichen Woodland	Lichen Woodland
DRY	Heath-Lichen	Heath-Lichen	Heath-Lichen Woodland	Heath-Lichen Woodland	Heath-Lichen Woodland
	Shrub-Heath (birch)	Shrub-Heath	Shrub-Heath	Shrub-Heath	
		Shrub-Heath Woodland Shrub Woodland	Shrub-Heath Woodland Shrub Woodland	Shrub-Heath Woodland	
MOIST	Heath-Herb (solifluction)	Heath-Herb	Moss-Lichen Woodland	Moss Forest	Moss Forest
	Heath-Sedge-Moss	Heath-Sedge-Moss (tussock tundra)	Moss Forest Shrub-Herb Forest (alluvial)	Shrub-Herb Forest	Shrub-Herb Forest
	Shrub Thicket (riparian)	Shrub Thicket	Shrub Thicket	Shrub Thicket	Shrub Thicket
WET	Heath-Lichen Bog Heath Bog (peat polygons)	Heath-Lichen Bog Heath Bog	Bog Forest Bog Woodland Heath-Lichen Bog Heath Bog (polygonal peat plateaus) Lichen Bog Woodland	Bog Forest Bog Woodland Heath-Lichen Bog Heath Bog Lichen Bog Woodland	Bog Forest Heath Bog (fire type)
SATURATED	Shrub-Sedge Fen Sedge Fen Sedge Meadow Marsh	Shrub-Sedge Fen Sedge Fen Sedge Meadow Marsh	Shrub-Sedge Fen Sedge Fen Sedge Meadow Marsh	Shrub-Sedge Fen Sedge Fen Sedge Meadow Marsh	Shrub-Sedge Fen Sedge Fen Sedge Meadow Marsh

Heath-Lichen-Grass

Ledum decumbens
Vaccinium vitis-idaea
(Empetrum nigrum)
Arctostaphylos alpina (HS)
Cornicularia divergens (HS)
Cetraria cucullata (HS)
C. nivalis
(Alectoria nitidula HS)
(A. ochroleuca HS)
Calamagrostis purpurascens
Hierochloë alpina (HS)
Luzula confusa (HS)
Silene acaulis

Moss-Lichen Woodland; Moss Forest

(increasing tree density favours bryophytes over lichens; tree species in moderately close to close stands on moist slopes)

Picea mariana
P. glauca
Betula papyrifera
Pleurozium schreberi
Hylocomium splendens
Ptilidium ciliare
Dicranum spp.
Cladina rangiferina
C. stellaris
C. mitis
Vaccinium vitis-idaea
Ledum groenlandicum

Shrub-Herb Forest (on rich alluvium, trickle drainages; all are 'Boreal' species)

Picea glauca
Betula papyrifera
Salix bebbiana
S. pyrifolia
Viburnum edule
Ribes triste
Rubus idaeus
Equisetum pratense
Dryopteris spp.
Rubus acaulis
Galium triflorum
Lycopodium annotinum

Shrub Thicket

Alnus crispa
Salix planifolia
S. Bebbiana (B)
Betula glandulosa

Shrub Heath; Shrub-Heath Woodland (similar except for presence of Picea mariana and P. glauca in woodland)

Betula glandulosa
Juniperus communis (B)
Vaccinium vitis-idaea
Ledum decumbens
L. groenlandicum
Empetrum nigrum
Loiseleuria procumbens

Cladina mitis

C. rangiferina
Cladonia uncialis
C. amaurocraea
Polytrichum piliferum
Ptilidium ciliare
Cetraria nivalis
C. cucullata (HS)
Alectoria nitidula (HS)
A. ochroleuca (HS)
Stereocaulon paschale

Heath-Lichen; Heath-Lichen Woodland; Lichen Woodland

(similar except for the relative abundance of heaths and the treelessness of Heath-Lichen)

Picea mariana
P. glauca (on alluvium and outwash)
Pinus banksiana
Betula papyrifera
Vaccinium vitis-idaea
V. uliginosum
Ledum decumbens
Loiseleuria procumbens
Arctostaphylos alpina (HS)
(Ledum groenlandicum)
(Empetrum nigrum)
Cetraria nivalis
C. cucullata
Cladina mitis
(C. rangiferina)
Cladonia amaurocraea
(C. deformis)
Alectoria nitidula (HS)
A. ochroleuca (HS)
Cornicularia divergens (HS)
Stereocaulon paschale
Polytrichum piliferum
(Pleurozium schreberi)
(Ptilidium ciliare)
(Dicranum spp.)

Heath-Lichen Bog; Bog Woodland

(higher cover of subarctic lichens on the open bogs than under woodland)

Picea mariana
Vaccinium vitis-idaea
V. uliginosum
Betula glandulosa
Ledum decumbens
L. groenlandicum
Andromeda polifolia
Empetrum nigrum
Rubus chamaemorus
Sphagnum fuscum
S. nemoreum
Cladina rangiferina (B)
C. stellaris
C. mitis
Cladonia amaurocraea
C. uncialis
C. deformis
Cetraria nivalis

C. cucullata (HS)Sedge FenCarex magellanicaC. limosaC. rarifloraEriophorum brachyantherumAndromeda polifoliaLedum groenlandicumSphagnum ripariumS. magellanicumS. nemoreumAulacomnium palustreTomenthypnum nitensSedge Meadow; MarshCarex rotundataC. membranaceaC. aquatilisC. stansEriophorum spissumScirpus caespitosusAndromeda polifoliaVaccinium vitis-idaeaBetula glandulosaArctophila fulvaDicranum spp.Sphagnum spp.**5. VEGETATION REGIONS AND SUBREGIONS**1) High Subarctic: Shrub Tundra

In this subregion, spruce and tamarack are inconspicuous, occurring only here and there as low clumps. Permafrost features frequently appear on upland mineral soils where they break the patterning of the black (Cornicularia) and yellow (Cetraria) lichens.

Larsen (1972) classified communities in northern Keewatin according to physiography, pointing out that the vegetation is strongly influenced by position on slope, which controls exposure and moisture regime. Gubbe (1976) reviewed the work of Larsen, Ritchie, and others, presenting a comprehensive classification of types based on his own extensive studies. From dry to wet on a physiographic continuum, his communities are:

- 1) Lichen-steppe (dark Cornicularia-Hierochloë) on polygonally fissured crests, with low heaths and mosses in the fissures.
- 2) Lichen-heath (light Cetraria-Vaccinium-Empetrum) on upper slopes.
- 3) Snowpatch Lichen-heath (dark Cetraria-Cassiope) with mosses on slopes.
- 4) Dwarf-shrub tundra (Betula-Salix in the south, Cassiope-Ledum in the north) on turf mounds and other minor solifluction features.

5) Tussock tundra (Sphagnum-Ledum-Eriophorum) on very moist lower slopes.

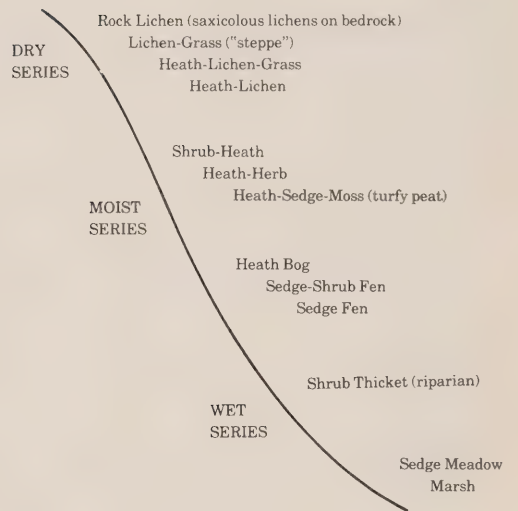
6) Sedge meadow (Carex-Eriophorum-Scirpus); polygonally patterned where the wet substratum is sandy.

7) Riparian shrub (Alnus-Salix-Equisetum in the south, Salix-Calamagrostis-Anemone in the north).

8) Marsh (Carex, Arctophila).

The types are similar in many respects to those described by Rowe et al. (1977) eastward in Keewatin, near Rankin Inlet. They are also recognizable within the LRMA as shown by the generalized catena in Figure 19.

Figure 19: Generalized catena of vegetation types of the High Subarctic Shrub Tundra



The Lichen-Grass and Heath-Lichen-Grass types occur on polygonally patterned streamlined till crests, and comprise a mixture of very dark wiry lichens with tufts of grasslike plants and dwarf heaths. Heath-Lichen has several forms; a dark community where the heaths are intermixed with the blackish Cornicularia and Alectoria, and a light community where the lichens are yellow Cetraria on gentler, less exposed slopes. Shrub (birch)-Heath tends to occur on lower, moister positions, although the community may be very sparse and open on south slopes of eskers.

Heath-Sedge-Moss is a hummocky thin-peat community on moist slopes and northern exposures; the prominent mosses are species such as Aulacomnium and Dicranum, contrasting with the slightly wetter Sphagnum-dominated Heath Bog. Heath-Herb mixtures are usual on frost-patterned or soliflucting slopes. Sedge Fen and Shrub-Sedge Fen mark seepage tracks and lower slopes. Shrub Thicket (chiefly Salix) borders streams and confined drainages. Lowland flats support Sedge Meadow (Carex and Eriophorum), while Marsh (Arctophila and Hippurus) occupies shallow permanent water in depressions.

2) High Subarctic: Forest Tundra

This subregion of the High Subarctic lies between the southern boundary of the Shrub Tundra 'tree form line' (marking the approximate limit of occurrence of spruce and tamarack as recognizable trees) and the northeastern boundary of the Low Subarctic Lichen Woodland at treeline (where tundra begins to dominate the landscape and tree cover, comprising less than 50%, is confined to the lower slopes and drainages). Permafrost features are mostly limited to organic terrain where eroded polygonal peat plateaus (high-center peat polygons) are characteristic.

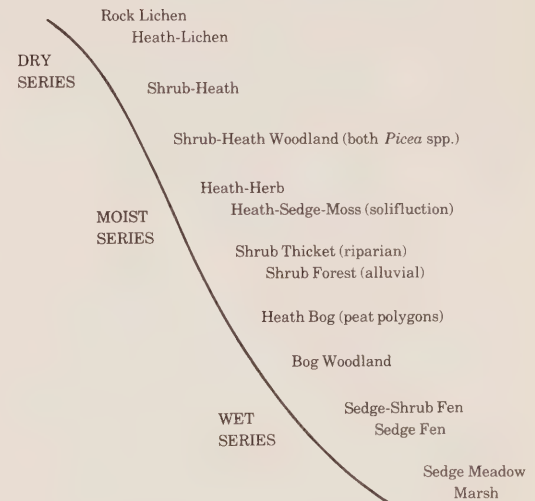
Ritchie (1959, 1960) defined the 'forest-tundra' in northern Manitoba as dominated on the uplands by 'heath tundra' (ericoid shrubs and fruticose lichens), while on the lowlands scrubby black spruce and white birch occupied more than 20% of the mesic sites. His physiographically based descriptions indicate the following continuum of communities, from dry to wet:

- 1) Heath tundra (Ledum, Empetrum, Vaccinium) on dry upland convexities, both till and outwash.
- 2) Shrub-heath spruce woodland, both white spruce and black spruce types, on the south slopes of minor moraine ridges, on eskers, raised beaches, etc.
- 3) Shrub woodland (Picea mariana and Larix laricina with Salix planifolia) in moist lowlands.
- 4) Shrub forest (Picea glauca, with Salix and Viburnum) on moist alluvium.
- 5) Shrub thicket (Salix, Betula, Alnus) on moist lower slopes and river banks.
- 6) Heath-herbs on moist cryoturbated surfaces (nonsorted circles).
- 7) Heath bog consisting of polygonally patterned permafrost peatland with an ericaceous cover.
- 8) Fen in wet drainages, with Carex, Scirpus, Eriophorum, and sometimes Betula

glandulosa and Larix laricina.
9) Meadow and Marsh.

The types are similar to those recognized by others who have examined the same subregion (Larsen, 1965; Maini, 1966; Kelsall *et al.*, 1971; Gubbe, 1976). With a few changes in terminology, all can be accommodated in the generalized catena in Figure 20.

Figure 20: Generalized catena of vegetation types of the High Subarctic Forest Tundra



The Heath-Lichen, Shrub-Heath, and Heath-Herb types are similar to those in the Shrub Tundra previously mentioned. Woodland types begin to appear, however, on outwash and lower moraine slopes. The hummocky Heath-Sedge-Moss (called 'tussock muskeg' by Larsen, 1965) is a shallow-peat lower slope type. Heath Bog is residual peatland that is treeless, polygonally patterned with ice-wedge fissures, and frequently eroding (Zoltai and Tarnocai, 1975). Bog Woodland describes the sparsely treed peat plateaus that begin to appear near the southern and western borders. Shrub Thicket and Shrub Forest are the rich alluvial types. The organic wetlands carry Fen and the mineral wetlands Meadow and Marsh, as in the preceding subregion.

3) Low Subarctic

Lichen Woodland or Heath-Lichen Woodland is the distinctive and typical vegetation of this extensive area that lies between the High Subarctic Forest Tundra treeline and the High Boreal closed coniferous forest. Kershaw (1977) has comprehensively reviewed the literature on the vegetation of these "northern boreal lichen woodlands in Canada", with particular attention to succession and the role of fire. He concluded (p. 398) that "the maintenance of the lichen cover is completely dependent on regular burning before canopy closure". However, the widespread occurrence of the type in a distinct belt or zone, plus evidence that very old woodlands (in excess of 300 years since fire) remain open, casts the hypothesis in doubt. We assume that, given the particular Precambrian terrain, Lichen Woodland is a stable, self-perpetuating type either with or without fire. Therefore a separation of the Low Subarctic from the neighboring High Boreal as a regional unit is justified.

In another recent study, also focussed on fire recurrence and succession, Johnson (1977) identified six vegetation types on upland mineral soils in the LRMA. Four are dry-site open stands of jack pine, black spruce and white birch, with lichens and/or shrub birch beneath (Heath-Lichen and Shrub Woodlands). The other two are closed-crown forests of black spruce and white spruce-white birch, with feather moss or shrub undercover on mesic sites (Moss and Shrub Forest).

The Low Subarctic vegetation types in the literature can readily be related to the typology first proposed by Hustich (1949). This ease of recognition from paper to paper reflects the simplicity of the terrain and the relatively few dominant species. Stony moraine uplands break sharply into peat-covered lowlands, and black spruce dominates both major landforms. Types parallel the moisture gradient in an evident way, as shown in Hare's (1959) adaptation of Hustich's ecological series for subarctic woodlands east of Hudson Bay (Table 20).

Black spruce is ubiquitous and jack pine is the next commonest tree in the LRMA lichen woodlands. It is most frequent on bedrock-controlled thin drift and on outwash plains. White spruce is confined to alluvium and water margins, and to hilly coarse stratified drift (eskers and kames). Tamarack borders fen tracks in peatlands, or pioneers on the lowlands after fire. However, the main influence of fire superimposed on the simple

Table 20: Vegetation types in ecological series for subarctic woodlands east of Hudson Bay (after Hare, 1959)

Very Dry Series

Rock desert) mostly without vegetation
Sand)

Dry Series

Lichen-shrub (stunted conifers)
Open lichen woodland (dwarf birch common)
Close lichen woodland (trees closer together; slightly moister)
Shrub woodland (abundant shrubs, scattered dwarfed trees)

Moist Series

Birchwood (on burned areas; a successional stage to coniferous forest)
Mixed forest (closed-crown conifer and deciduous, with abundant mosses)
Coniferous forest (moss and herb understory, common on well-drained valley floors)

Wet Series

Muskeg (bog forest with stunted trees)
Bog (treeless Sphagnum peat)
Fen (sedge meadow with occasional stunted conifers; Sphagnum rarely present)
Bog complex of permafrost areas (patterned peatland and palsas)
Encroachment (marginal vegetation around water bodies, usually with Alnus)
Alder and willow thickets (riparian shrubs)

ecological pattern is to bring white birch into temporary prominence on most sites. After about 100 years, the pre-fire compositions are restored and birch remains as a sprinkling through the predominantly coniferous forest. Successional changes are mostly confined to the non-sprouting lichens, mosses, and herbs as they invade and respond to the shading that accompanies regeneration and growth of the dominant trees.

Because of their areal extent, the peatlands merit particular attention. The typical form is a peat plateau or raised permafrost bog, bordered by open water or fen on the wet lowland side and by a narrow strip of forested shallow peat (bog border) that abruptly passes into Lichen Woodland on the dry upland mineral soils. Surfaces are hummocky due to the two main peat formers: Sphagnum fuscum and Sphagnum S. nemoreum. Where these species are vigorously alive, the networks of hollows between their mounds are occupied by Cladina rangiferina, C. stellaris and Cladonia amaurocraea; where they are dead, due to fire or climatic severity, a dense mat of lichens covers the entire surface (Heath-Lichen Bog) and Cladina mitis, Cladonia coccifera, and Cetraria nivalis are prominent.

On level terrain, the peat plateau surfaces are usually pitted with melt-out hollows whose pools carry a 'poor fen' vegetation of *Sphagnum recurvum*, *S. riparium*, *Carex limosa*, and *C. paupercula*. On sloping terrain there is little surface water; drainage is established by thermokarst features in the form of downslope 'fen tracks' that give a 'rilled' appearance to many peat plateaus. The vegetation of the fen tracks is much the same as that of the shallow peats associated with eroding high-centered peat polygons in the High Subarctic, dominated by *Scirpus caespitosus*, *Eriophorum spissum*, and *Carex membranacea*. On air photos in drumlinized till, rilled peat plateaus can frequently be seen as aprons on the drumlin flanks. Presumably there are aquifers in the coarse till, the upper edges of the peat aprons marking the line of water discharge from rain and snowmelt on the surface above.

Both the sink-hole peat plateaus on flats and the rilled peat plateaus on slopes can be wooded or treeless. The latter condition is often due to fire but, toward treeline to the east and north, it reflects an increasingly severe climate. This has been recognized on the ecological map by separating the Low Subarctic according to the consistent presence or absence of trees on permafrost peats.

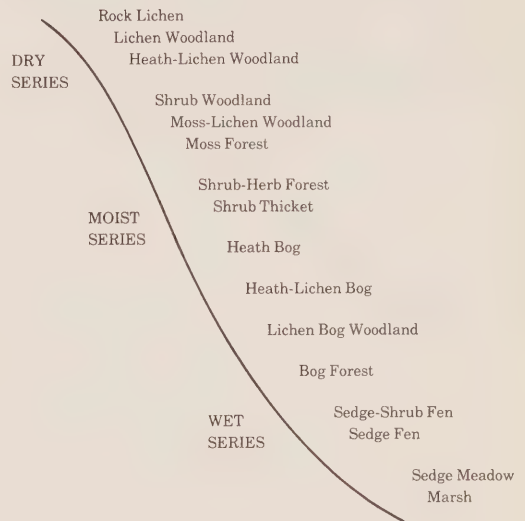
Treeless peat plateaus have several other important characteristics; they are deep (as much as 10 m), lichen-covered, polygonally patterned by ice-wedge fissures, and they often front on water bodies where wave erosion has exposed cusped peat cliffs. The depth of the residual fibric *Sphagnum* peat suggests that the deposits formed under an earlier warmer climate, later to be invaded by permafrost (Zoltai and Tarnocai, 1975). The cliffs also suggest that the peatlands were at one time much more extensive, filling the bays and basins of what are now lakes. The lichen cover on dead *Sphagnum* mounds indicates a current quiescent state of peat building, possibly due to surface drying as the ice-wedge fissures deepen in response to climate change.

Near the Low Subarctic-High Subarctic transition, there is much evidence of permafrost melting in peatlands. The ice-wedges have receded as the fissures have deepened and widened, leaving high-and-dry peat polygons with eroding dark brown fibric surfaces. In some places on gentle slopes, the peatland has a striking striped structure due to the alternation of narrow dark bog ridges with broad light fen patches, somewhat similar in appearance to the 'string peatland' which, according to Stanek (1977),

"in typical form occurs near the tree line". However, the net form of the bog stripes and their downslope transition to eroded peat plateaus casts in doubt their relationships to string bogs and string fens as usually recognized. Until something of their genesis is known, they should more safely be described as 'striped bog-fen complexes'.

Vegetation types recognized in the LRMA are much the same as those of the Hustich-Hare scheme as shown in Figure 21.

Figure 21: Generalized catena of vegetation types of the Low Subarctic



4) High Boreal: Shield Uplands

There is now good evidence from northern Manitoba (Ritchie, 1959) and northern Saskatchewan (Coupland and Rowe, 1969), as well as from these studies in the LRMA, that the boundary of the Low Subarctic (Lichen Woodland or open coniferous forest) and the Boreal (closed coniferous forest) was placed too far south and west by Halliday (1937) and Rowe (1972). The Northern Coniferous Section of the latter authors is more extensive than was formerly believed, and it is apparent that the limit of closed coniferous forest on the Shield runs from near the southern end of North Knife Lake in Manitoba westward to about the longitude of Uranium City on the

N.W.T. border, then northward to the Snowdrift River just south of the East Arm of Great Slave Lake.

The redrawn boundary takes a large piece of the LRMA out of the Northwestern Transition Section (B.27, open woodland, Rowe, 1972) and places it in the Northern Coniferous Section (B.22, closed forest). Here, on mesic upland till-over-bedrock sites, the forest is dominated by moderately dense black spruce with a ground cover of feather mosses (*Pleurozium*, *Hylocomium*, and *Dicranum*). After fire, mixtures of white birch, black spruce, and jack pine prevail. The pine is also prominent on rock ridges and outwash; white spruce grows to large size on alluvium and sand ridges; tamarack accompanies black spruce on bog and fen peatlands. Ritchie's (1956) description of the types in northern Manitoba apply reasonably well in the LRMA.

Extensive bedrock outcrop and thin drift over bedrock impose a dry open-woodland character on many black spruce and jack pine upland areas. From the air they resemble lichen woodlands and so are well described as 'Rock Lichen' types. At the other moisture extreme, on low wetlands, some peat soils are also lichenous and sparsely tree-covered. Such wooded landforms, often pitted with 'melt out' thermokarst hollows, signify the presence of permafrost in uplifted peat plateaus. Following fires that remove both black spruce and lichens, the peat plateaus remain for years as 'Heath Bogs', densely clothed with *Ledum groenlandicum*.

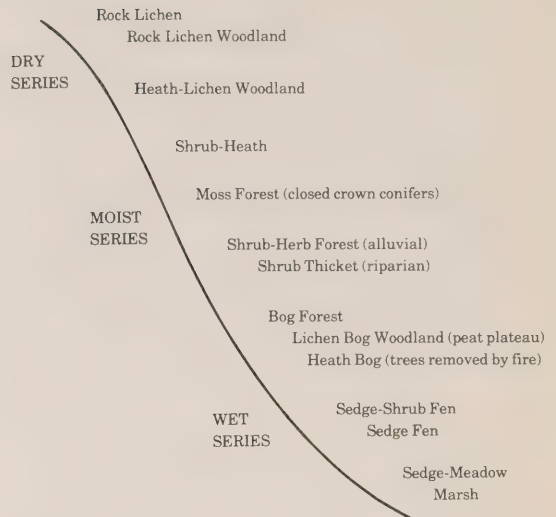
The sequence of community types, based on the non-tree vegetation, is shown in Figure 22.

In the High Boreal, Lichen Woodland is confined to rock outcrop shallow tills and coarse outwash landforms. Moss Forest becomes an important type on slopes and imperfectly drained lowlands. Peat plateaus with open tree cover are the typical Lichen Bog Woodlands, dominated by Labrador tea after fire.

5) Mid Boreal: Slave River Lowlands and East Arm of Great Slave Lake

The combination of relatively low altitude, water, and lacustroalluvial sediments confers the most favourable climatic and growth conditions on the Slave River Lowlands at the west side of the LRMA. Glacial lake flooding extended relatively fertile soils from the Slave River to about the 300 m contour, reflected today in the mosaic of Shrub-Sedge Fens and aspen-spruce forests that occur on mesic sites west of the line from Pilot Lake

Figure 22: Generalized catena of vegetation types of the High Boreal (Shield Uplands)



in the south to McDonald Lake in the north (approximately along 111° longitude). Close forests of black spruce and of jack pine occupy the wetter and drier sites respectively, and the same species form open 'Rock Lichen' woodlands where the lacustrine and till veneer have been scoured from the bedrock rises. There are also extensive bog-fen patterns on whose peat ridges and plateaus the spruces and tamarack are prominent, flanked by willow-shrub thickets.

The East Arm terrain is a variant of the same Upper Mackenzie B.23a forest section (Rowe, 1972). Glacial Lake McConnell invaded from the lowlands to the west, raising the water level in the basin some 150 m above the present-day lake and creating marginal deposits of clay, silt, and deltaic sand. The terraced Old Fort Reliance sand plain is an example of the latter.

Kelsall *et al.* (1971) characterized the vegetation of the East Arm as 'Forest Fringe', noting that closed-crown moss forests of black spruce and white spruce exceed 15 m in height on favourable sites. They also alluded to the occasional occurrence of patches of aspen and balsam poplar, as well as to open pine, spruce and tamarack woodlands that grow on the more

extreme dry and wet soils. Fire introduced white birch into the composition of many stands.

In an earlier, wider-ranging description of the forests from Lake Athabaska to Great Slave Lake, Raup (1946) distinguished several important communities including the ubiquitous black spruce-tamarack bog, alluvial white spruce (rich in shrubs and herbs), and the Precambrian upland jack pine types. He was impressed with the "park-like white spruce" forests around the East Arm, supposing the type to be very common immediately south of treeline, both to the east and the west. Our survey suggests that this white spruce lichen-heath woodland is indeed widespread through the LRMA, but it is mostly confined to coarse alluvial and lacustrine materials (for example, the floodplains of the Snowdrift, Taltson, and Thoa rivers as well as on the raised terraced deltas of the East Arm).

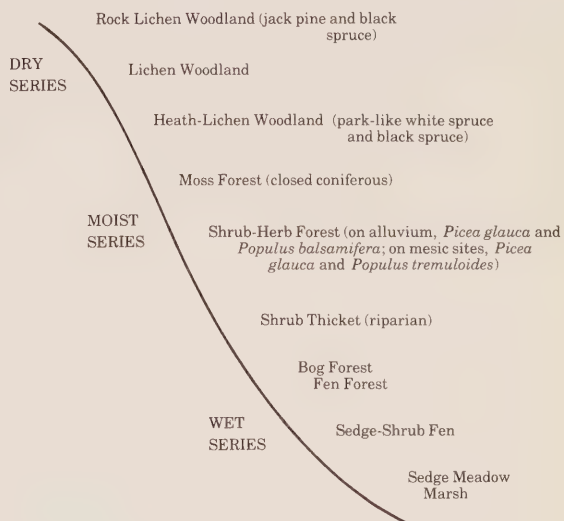
It is azonal, rather than zonal, as Raup's map suggests. The type is remarkable for its tall, narrow-crowned trees, the lack of broadleaved shrubs, and the prominence of Stereocaulon lichen in the ground cover.

The chief vegetation types of the two lowland ecodistricts are summarized in Figure 23.

Mostly the rock outcrops bear woodland except immediately after fire. Moss and Shrub-Herb forests are common, the latter with Populus

species joining the white spruce which, with tamarack, often appears on wet calcareous fen peat. Fen types are more abundant than Bog types on the Slave River Lowlands.

Figure 23: Generalized catena of vegetation types of the Mid Boreal (Slave Lowlands)



SECTION N

FIRE IN THE LRMA

FIRE IN THE LRMA

A better understanding of fires and of their role in subarctic ecosystems was the original motive for studies in the LRMA. Fires are destructive in the short-term view but they are also renewing over the long term; by initiating new growth in a mosaic pattern, they maintain the landscape diversity that is both attractive and productive for wildlife and for man. Some of the fire findings that relate to the ecological map are briefly discussed.

Figure 24 shows the distribution and sizes of fires from 1967 to 1976 in the LRMA, based on maps made up by the Northwest Lands and Forests Fire Center at Fort Smith. Only the major burned areas are drawn to approximate scale; the small dots represent fires of variable sizes, the largest ranging up to several thousand hectares. The large blacked-in areas of the west side, dominated by the massive Rutledge Lake fire of 1971, suggest that the High Boreal forestland (between about 110° and 112° longitude, south of the East Arm and west of the Taltson River) is particularly fire-prone. This is to be expected in a landscape where there is fuel continuity (closed-crown forest) on surficial materials that are conducive to rapid surface drying (bedrock-controlled drift). Also indicative of high fire hazard in the same ecodistrict is the prominence of *Pinus banksiana*. It thrives on the coarse stratified drift and in the fissures of rock outcrop where, relatively free from competition with *Picea mariana*, it regenerates and provides a source of seed for surrounding terrain even after short-interval fires.

Eastward from 110° longitude, to the LRMA boundary at 104° longitude, the sizes and numbers of fires show no apparent pattern except for a slight decrease from High Boreal to Low Subarctic. Large burns are scattered through the Lichen Woodland from the eastern end of McLeod Bay on Great Slave Lake to Selwyn Lake in the southeast corner. Deep drift areas such as the Abitau-Dunvegan Ecodistrict (LS3) in the central south seem to have experienced less extensive fires than shallow till/bedrock areas such as the McKinlay Ecodistrict (LS4) north of the East Arm, though perhaps differences in length of fire season are involved.

It is notable that fires are common right up to treeline and within the Forest Tundra of the High Subarctic. Few fires have been reported in the Shrub Tundra. North of the East Arm, some sizeable fires have been

reported in the Forest Tundra vegetation although here, as mentioned earlier, there are problems in deciding on the ecological zonation. At any rate, there is a marked decrease in the incidence of fires between the south and north boundaries of the Forest Tundra, coincident with the gradual disappearance of woodland cover. In non-wooded terrain, the difficulty of detection plus a lack of concern for fires probably contributes to the rarity of reported incidences. Surveillance of the LRMA in the last decade has, however, been sufficient to give credence to the fire patterns illustrated.

The preceding interpretations are supported by an earlier study (Johnson and Rowe, 1975) in which the dates of ignition by lightning were analyzed. It was shown (Figure 25) that in May, fires are confined to the High Boreal Ecoregion in the west and to the vicinity of the East Arm. By June, fires had advanced to the eastern limit of the Low Subarctic Ecoregion. In July, the month of deepest incursion of ignition into the LRMA, fires were reported within the Forest Tundra. By August, the 'fire line' had retreated toward the southwest and virtually no fires were recorded in September.

The pulse of fires into the LRMA and out again between May and September has the interesting implication that the western High Boreal experiences four months of potential fire weather, the Low Subarctic (central south) has two to three months, and the Forest Tundra of the High Subarctic has only one month. Therefore, it may be that both fire incidence and fire size are related to the length-of-hazard season, and not only to the physiographic and fuel characteristics of the ecoregions and ecodistricts.

Based on the available fire sizes and dates, an average burning rate of 1% annually is about normal for the High Boreal Precambrian Uplands. Theoretically then, it might be expected that the southwestern quarter of the LRMA will be completely burned over every century (i.e., a fire rotation of 100 years).

Low Subarctic terrain will experience a lower burning rate, and a probable fire rotation of 150-200 years is postulated. Aging of trees in the Low Subarctic has in fact shown that stands older than 200 years are quite common.

Generalities about burning rates can be misleading, particularly over the short term, unless it is recognized that there may be lengthy periods when the weather favours many

fires, or none. Also, all sites within an ecoregion or ecodistrict are not equally susceptible. Topographic diversity, wet lowlands, and abundant large water bodies tend to confine fires, while the opposite terrain conditions are conducive both to large fires and to frequent recurrences on the included sites. Fires are mapped by their perimeters, within which there may often be a high percentage of unburned inclusions (50% is not unusual). Therefore, fire data seldom provide exact areal information on annual burns, which introduces a fundamental error into estimates of fire rotation periods.

Two aspects of fire that have important implications for soils, vegetation structure, animal habitat, and water relations are frequency and intensity. The latter is difficult to assess in an ecologically meaningful way because its importance lies not in energy release *per se* but rather in how such energy release affects terrain. Much depends on time of year and on preceding and current weather conditions. For example, an intense fire in the spring may have little effect on soils because they are still frozen, whereas a fire of the same intensity in late summer may remove all organic surface material and initiate erosion. Taking a simplified viewpoint that ignores such seasonal variations, the High Boreal Ecoregion -- where rate of fuel accumulation, drying rate of substratum, and length of potential fire season are all high -- is likely to experience the most intense fires.

Fire recurrence is a somewhat simpler concept. A common-sense prediction is that the intervals between fires for any given place (the fire frequency) will relate to air-mass climate, including length of the fire-hazard season, and to the landform-vegetation patterns of local terrain. An

ecological map that integrates these variables in ecoregions, ecodistricts, and ecosections provides the necessary framework for statistical examination of fire recurrence intervals. As with intensity, fire frequency will predictably be higher in the Boreal than in the Subarctic, higher on smooth-topography plains than on heterogeneous terrain, and higher on well-drained uplands than on poorly drained lowlands.

These propositions are supported by two thesis studies carried out under the LRMA program. Johnson (1977) examined vegetation change and fire recurrence on upland (mineral soil) sites. He fitted the frequencies of fire intervals over a range of sites to a mathematical distribution (Weibull), thus providing a tentative basis for predicting fire recurrence probabilities according to regional location and topographic terrain roughness. The model predicts a lengthening of intervals between fires from southern and western forested regions toward treeline, and increased susceptibility to local burning from rough to smooth topography. Thus, the probabilities of frequent or infrequent burning are related to landforms within a regional framework as provided by the ecological land map. Jasieniuk (personal communication) adopted exactly the same approach to studying peatlands. She found that fires were less frequent in these lowland types than on the adjacent mineral soils; on the uplands, however, the vegetation was generally restored to its pre-fire composition directly after disturbance. Thus, fire creates a mosaic of stand ages without drastically affecting their floristic composition. This means that succession, in the classic sense of time sequences of different communities, is less apparent in the Subarctic than in more favourable climates.

Figure 24: Distribution and sizes of fires in the LRMA from 1967 to 1976. Only the large fires are drawn to scale.

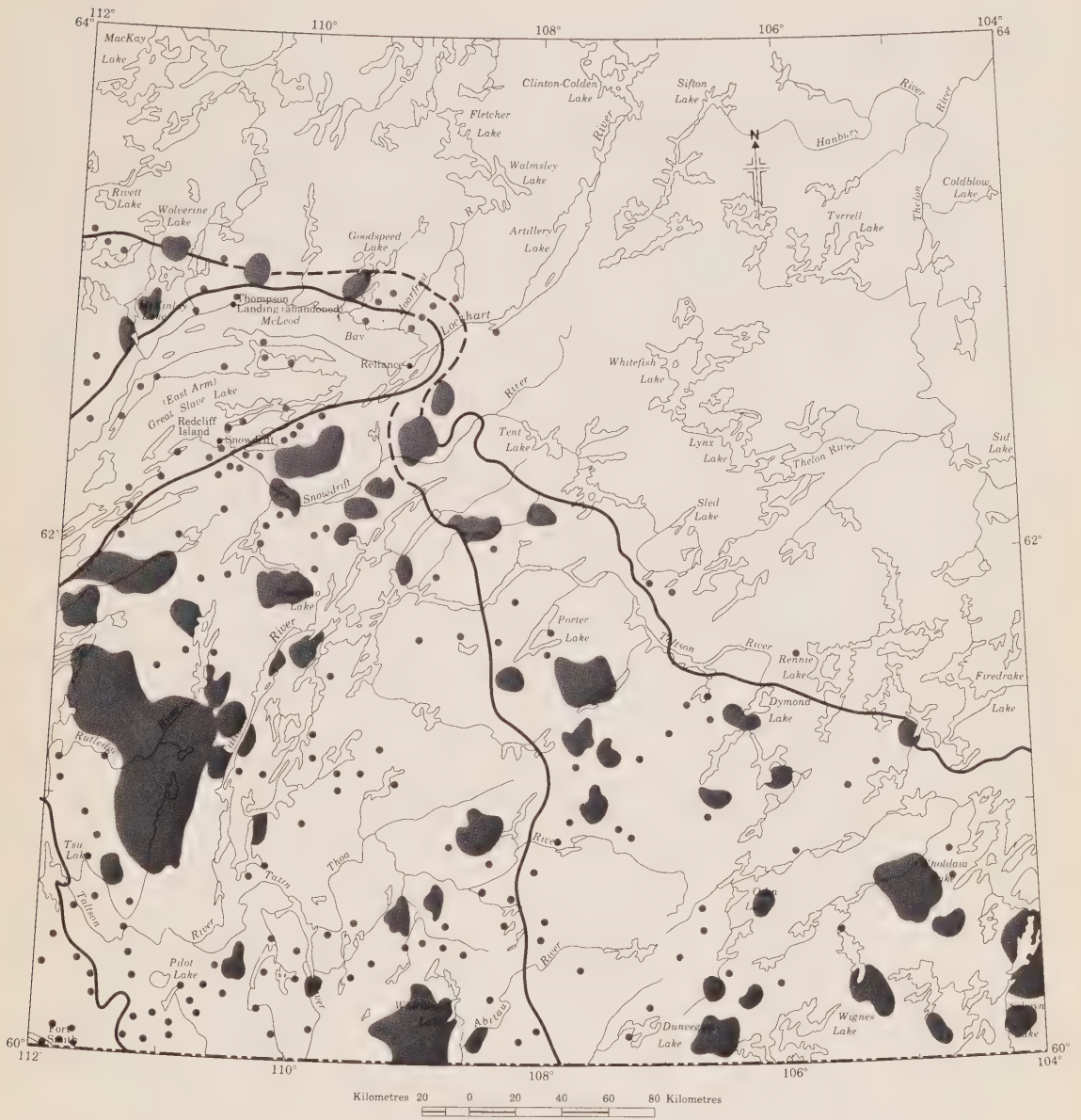
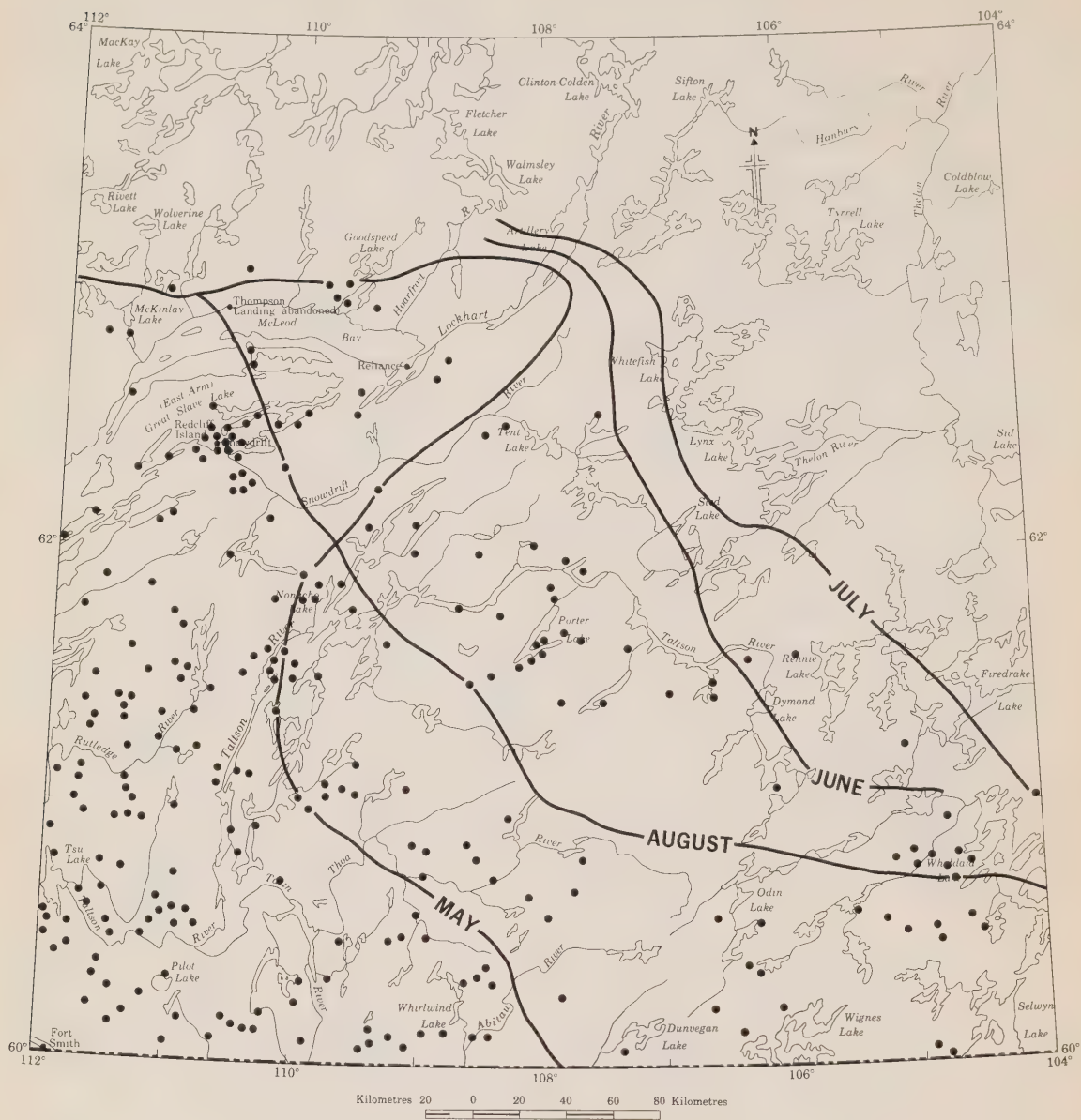


Figure 25: Location of fires in the Lockhart River Map Area from 1966 to 1974. Dots mark locations of fires; lines indicate monthly limits of fires as they advance northeastward in May, June, and July and retreat southwestward in August.



SECTION O

WILDLIFE AND HABITAT

WILDLIFE AND HABITAT

The wildlife component can readily be included in ecological land classification when a strong vegetation-habitat framework has been established, since plants provide food and shelter for animals. Such an integration of fauna with vegetation-habitat was attempted by Merriam (1894), who divided the North American continent into three primary transcontinental Regions, with further subdivisions into Life Zones. According to Merriam, the LRMA is part of the Boreal Region and includes three Life Zones -- the Arctic-Alpine (our High Subarctic), the Hudsonian (our Low Subarctic and High Boreal), and the Canadian Zone (our Mid Boreal).

A second approach to broad natural landscapes uses the 'Biome' concept of Clements and Shelford (1939). According to their classification, our High Subarctic is included in the Tundra Biome, our Low Subarctic is part of the Taiga Biome, and our High and Mid Boreal ecoregions are parts of the Coniferous Forest Biome.

Both the above schemes, corresponding to our regional classification, have proved useful in a very general way for students of wildlife. However, the breakdown is not sufficiently detailed for the delineation of habitats on which the management and preservation of wildlife must be based. Placing the Muskox as an inhabitant of the High Subarctic Ecoregion (Arctic-Alpine Zone, Tundra Biome) or the Ovenbird as a species of the Mid Boreal Ecoregion (Canadian Zone, Coniferous Forest Biome) is not particularly helpful. A finer division is needed, separating habitats at the level of the ecoregion on maps at scales of 1:60,000 to 1:250,000. Such mapping will enable a user to distinguish prime summer feeding range for Muskox as Shrub Thicket, winter range as Heath-Lichen Bog, Heath Bog, and Sedge Meadow, and nesting habitat of the Ovenbird as Shrub-Herb Forest.

Although the vegetation-terrain information in the present study is believed to be adequate for habitat delineation, no detailed mapping was done. As with the treatment of the LRMA vegetation, attention has been focussed on wildlife indicator groups that characterize the four ecoregions (Table 21). In addition to limited field observations in the LRMA, information on habitat requirements and distributions has been taken from Godfrey (1966) and from Banfield (1974). For the birds, references concern only summer breeding habitat.

For the LRMA, 169 species of breeding birds have been reported, of which only 26 are ubiquitous and are found in all four ecoregions; 26 species are restricted to the Mid Boreal, another 51 extend into but not beyond the High Boreal, and 73 reach their limits in the Low Subarctic. There are no species confined to the Low Subarctic, and it shares only 3 species with the High Subarctic, to whose tundra habitats 16 species are limited.

There are 49 species of mammals in the LRMA, of which 7 are ubiquitous. Six species are restricted to the Mid Boreal and 13 extend through it to the High Boreal. An additional 16 occur only in the High Boreal and Low Subarctic, while 5 are confined to the High Subarctic. One species is found only in the Low and High Subarctic ecoregions, while another occurs in these ecoregions plus the High Boreal.

The distributions of birds and mammals indicate that the High Boreal Conifer Forest and the Low Subarctic Lichen Woodland, both on Precambrian Shield terrain, are faunistically similar. There are no unique habitats in the Low Subarctic, for it is a floristically depauperate relative of the neighboring High Boreal. However, there is a noticeable separation on both sides of these two ecoregions, for the Mid Boreal has its own characteristic assemblage, as does the High Subarctic.

As suggested above, the distributions of the wildlife reflect vegetational differences which characterize the ecoregions. Mixed deciduous and coniferous forest is the requirement of all Mid Boreal and many High Boreal birds; it is significant that many of the High Boreal species requiring mixedwood habitats occur only in the western half of the High Boreal Ecoregion, where deciduous trees and dense shrubbery are fairly common.

Approximately half of the species found in the Low Subarctic demonstrate a preference for the open and generally stunted coniferous growth characteristic of the ecoregion. The others frequent sites of denser, frequently deciduous vegetation such as Moss Forest, Shrub-Herb Forest, and Shrub Thicket.

Species of the High Subarctic prefer tundra landscapes or areas with only scattered wooded outliers. Over half of the species in the High Subarctic are either at or near the southern limits of their distributions, or are also found along the Arctic coasts and into the archipelago. The true tundra species reach their southern limits at the Forest Tundra ecotone.

Table 21: Animals associated with the ecoregions of the LRMA

HIGH SUBARCTICBirds

<u>Gavia adamsii</u>	Yellow-billed Loon
<u>Clangula hyemalis</u>	Oldsquaw
<u>Lagopus lagopus</u>	Willow Ptarmigan
<u>Pluvialis dominica</u>	American Golden Plover
<u>Ereunetes pusillus</u>	Semi-palmated Sandpiper
<u>Stercorarius parasiticus</u>	Parasitic Jaeger
<u>Stercorarius longicaudus</u>	Long-tailed Jaeger
<u>Anthus spinoletta</u>	Water Pipit
<u>Acanthis hornemanni</u>	Hoary Redpoll
<u>Zonotrichia querula</u>	Harris Sparrow
<u>Calcarius pictus</u>	Smith's Longspur

Mammals

<u>Lepus arcticus</u>	Arctic hare
<u>Spermophilus parryii</u>	Parry's ground squirrel
<u>Dicrostonyx torquatus</u>	Collared lemming
<u>Ovibos moschatus</u>	Muskox
<u>Rangifer tarandus</u> (summer)	Caribou

LOW SUBARCTICBirds

<u>Canachites canadensis</u>	Spruce Grouse
<u>Totanus flavipes</u>	Lesser Yellowlegs
<u>Erolia minutilla</u>	Least Sandpiper
<u>Sterna paradisaea</u>	Arctic Tern
<u>Surnia ulula</u>	Hawk Owl
<u>Bombycilla garrulus</u>	Bohemian Waxwing
<u>Dendroica striata</u>	Blackpoll Warbler
<u>Pinicola enucleator</u>	Pine Grosbeak
<u>Loxia leucoptera</u>	White-winged Crossbill
<u>Junco hyemalis</u>	White-eyed Junco
<u>Spizella arborea</u>	Tree Sparrow

Mammals

<u>Sorex arcticus</u>	Arctic shrew
<u>Sorex cinereus</u>	Masked shrew
<u>Tamiasciurus hudsonicus</u>	Red squirrel
<u>Clethrionomys rutilus</u>	Northern red-backed vole
<u>Rangifer tarandus</u> (winter)	Caribou

HIGH BOREALBirds

<u>Mergus merganser</u>	Common Merganser
<u>Accipiter striatus</u>	Sharp-shinned Hawk
<u>Haliaeetus leucocephalus</u>	Bald Eagle
<u>Larus canus</u>	Mew Gull
<u>Dendrocopos pubescens</u>	Downy Woodpecker
<u>Perisoreus canadensis</u>	Gray Jay
<u>Parus atricapillus</u>	Black-capped Chickadee
<u>Dendroica coronata</u>	Yellow-rumped Warbler
<u>Seiurus noveboracensis</u>	Northern Water-thrush
<u>Loxia curvirostra</u>	Red Crossbill
<u>Spizella passerina</u>	Chipping Sparrow

Mammals

<u>Tamiasciurus hudsonicus</u>	Red squirrel
<u>Clethrionomys gapperi</u>	Gapper's red-backed vole
<u>Synaptomys borealis</u>	Northern bog lemming
<u>Martes americana</u>	American marten
<u>Mustela erminea</u>	Ermine
<u>Rangifer tarandus</u> (winter)	Caribou

MID BOREALBirds

<u>Pelecanus erythrorhynchos</u>	White Pelican
<u>Aythya americana</u>	Redhead
<u>Bartramia longicauda</u>	Upland Plover
<u>Larus delawarensis</u>	Ring-billed Gull
<u>Larus pipixcan</u>	Franklin's Gull
<u>Chlidonias niger</u>	Black Tern
<u>Asio otus</u>	Long-eared Owl
<u>Bombycilla cedrorum</u>	Cedar Waxwing
<u>Sturnus vulgaris</u>	Starling
<u>Mniotilta varia</u>	Black-and-white Warbler
<u>Dendroica virens</u>	Black-throated Green Warbler
<u>Seiurus aurocapillus</u>	Ovenbird
<u>Geothlypis trichas</u>	Common Yellowthroat
<u>Pheucticus ludovicianus</u>	Rose-breasted Grosbeak
<u>Carpodacus purpureus</u>	Purple Finch
<u>Poocetes gramineus</u>	Vester Sparrow

Mammals

<u>Sorex obscurus</u>	Dusky shrew
<u>Myotis lucifugus</u>	Little brown bat
<u>Canis latrans</u>	Coyote
<u>Odocoileus hemionus</u>	Mule deer

SECTION P

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REFERENCES

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